

THE MARINE COMMUNITIES OF MARGARITA ISLAND, VENEZUELA

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ABSTRACT

The communities of rocky, sandy and muddy shores are analyzed and dominant species are recorded. The effect of some physical factors exposure to wave action is correlated with the composition of the most conspicuous communities. The applicability of Stephenson's general scheme zonation is discussed. From the results of this analysis an attempt is made to characterize and delimit the biogeographical province of the West Indies. At the end, a summary of the most common forms of marine plants and invertebrates of the area is given.

INTRODUCTION

Margarita is the largest of the islands in the Caribbean Sea off the coast of Venezuela that are actually a part of the east-west Caribbean or Coast Range. It lies 30 kilometers north of the mainland in 11°N lat. and 64°W long. It is composed of two mountainous islands joined together by two sand spits, between which is a large lagoon, Laguna de Restinga, open to the sea. The mountains average 100 meters high. The area to the east of Laguna Restinga, which also separates the two parts of the island, is nearly twice as large as the western part, which is locally called Macanao. The total area of Margarita is 1,150 square kilometers, its greatest length being 75 kilometers (Fig. 1).

Southward, between Margarita and the mainland, there are two small islands, Coche and Cubagua.

Most of the literature concerning the biology of the island has been written by Galtsoff (1950) in his report on the Pearl Fishery of Venezuela. This refers mainly to mammals and birds, and the economy of the pearl oyster. Johnston (1905) and others have reviewed the geology of the island. Very little is known of the hydrographical conditions.

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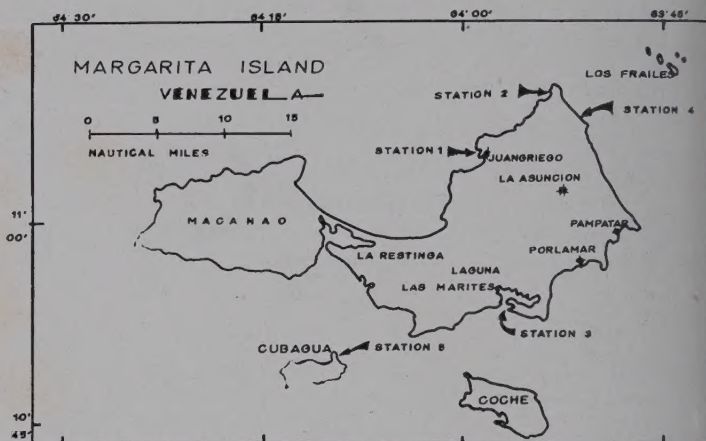


FIGURE 1. Map of Margarita Island, showing position of stations.

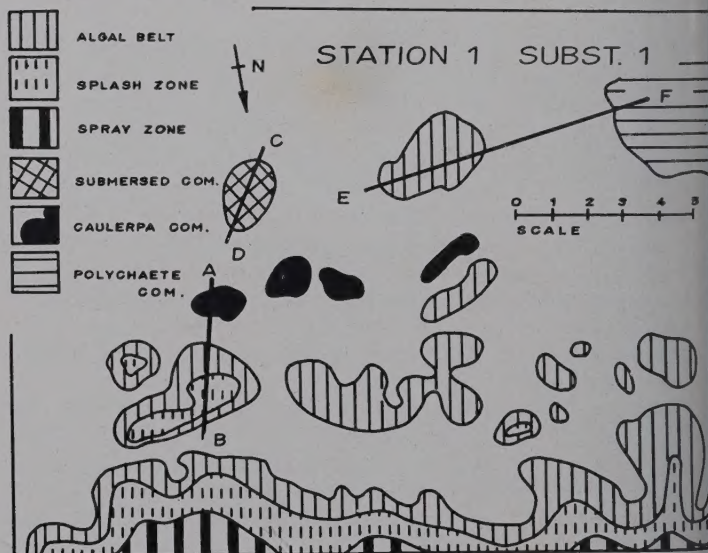


FIGURE 2. Station 1, substation 1. General arrangement of the zones.

s and biota of the inshore waters.

For several years, the Society of Natural Sciences La Salle (Sociedad de Ciencias Naturales La Salle), from Caracas, has been conducting an intensive study of the geography, geology, anthropology, history, and zoology of the area. During the summer of 1956 the author was asked to carry on the study of the biotic conditions in the waters of the island.

The present report summarizes the results obtained from data collected at that time.

The author is indebted to the Director and members of the Society who provided all the field facilities, and to Drs. Hilary B. Moore and Robert L. Voss, from The Marine Laboratory, University of Miami, for their tireless counsel. Dr. Voss identified several forms of invertebrates.

DEFINITION OF TERMS

Community Concept. There has been disagreement in the past

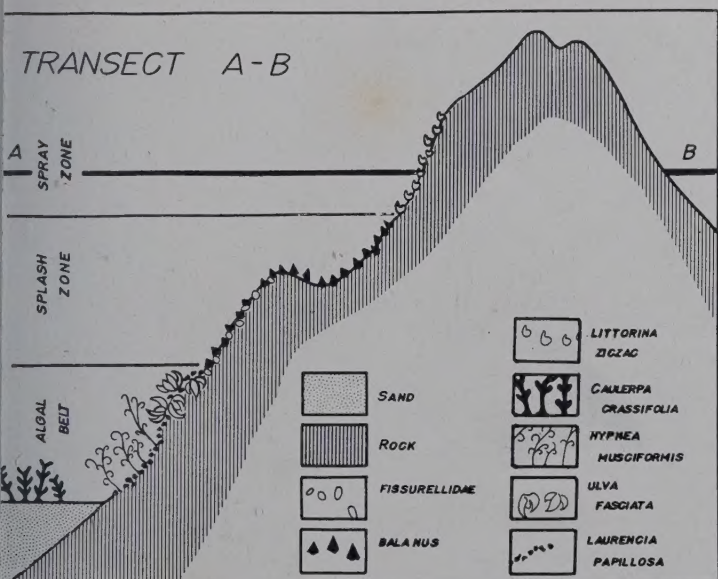


FIGURE 3. Station 1, substation 1. Transect A-B.

regarding the concept of animal and plant communities. In fact there are two main tendencies: one considers the community defined by the selective physical factors, another defines the community by composition or dominant organisms. In the following pages an eclectic position is adopted and I will consider as habitat the biotopes defined mainly by physical conditions. When the reunion of organisms creates new conditions, different from merely physical ones, it will be approached from the association side. Briefly, the terms used are:

Zone: A band or region in the shore, defined by physical conditions.

Association: A community dominated by more than one species that created special conditions for the secondary species different from the bare physical factors.

Consocieties: An association with one single dominant.

The word community is to be used in its broadest sense as a group of organisms, and belt is interchangeable with zone, but is used specially for bands of algae on the shore.

In the analysis of communities, all forms, whether algal or invert



FIGURE 4. Station 1, substation 1. *Littorina* down to the inferior part of the Balanoid zone.

te, are considered together as forming an indissoluble unit, but y the dominant and more common forms are cited. Further details found in the list of algae and invertebrates given at the end.

al Levels. In the current literature, tidal levels are usually denoted abbreviations or symbols. Mean sea level is indicated by M. S. L., in high and low water marks by M. H. W. and M. L. W., respectively. Every fortnight there is a spring tide, in which the tidal amplitude is larger (high water is higher and low water is lower) than the normal; in between there is a neap tide with an abnormally small amplitude. We therefore distinguish high and low water spring tide (H. W. S. and L. W. S.) and high and low water neap tide (H. W. N. and L. W. N.). Since the levels of these spring and neap tides vary according to the season, a distinction is made between mean and extreme values (for instance, M.H.W.S. and E.H.W.S.). The extremes occur only once or twice a year. In the following pages we will refer generally to two levels that we consider as critical: M. L. W. S. and M. H. W. S. that determine our three main zones: Spray, from the M. H. W. S. up, Splash, from M. H. W. S., down, and the Algal Belt, from the M. L. W. S. Equivalency of these zones with those of Stephen-



FIGURE 5. Station 1, substation 1. The polychaete pool.



FIGURE 6. Station 1, substation 1. The polychaete pool, detail at low water.

son are given elsewhere. In the absence of complete tidal data, I have used this simplified terminology, without any pretension of substituting the well-established names of the author mentioned.

STATIONS

Five Stations representing rocky, muddy, and sandy shores, as well as coral formation, were chosen. For the sake of simplicity each Station was divided into Substations, these representing peculiarities of each zone, but not necessarily a zone in itself.

List of Stations with Notations on Location and General Character
Margarita Island, August 1956.

Station 1. La Galera shores, near Juan Griego.

Subst. 1. Rocks more or less protected and submerged coral communities, down to 1.5 m water.

Subst. 2. Rocks by the side of Subst. 1, with tidal currents.

Subst. 3. Rocks and *Thalassia* field.

Station 2. Manzanillo shores, near Cabo Negro.

Subst. 1. Unprotected rocks.

- Subst. 2. Rocks with heavy wave action.
- Station 3. Sand bar at the entrance of Las Marites Lagoon.
- Subst. 1. Sandy shore open to the sea, with stones and decayed palm trunk.
- Subst. 2. Sandy shore, open to the Lagoon.
- Subst. 3. Stones on the Lagoon shores.
- Subst. 4. Semienclosed pools.
- Subst. 5. Muddy shore in the Lagoon.
- Subst. 6. Mangroves.
- Station 4. El Agua, near El Tirano.
- Exposed rocks, in the form of a point projecting from the shore.
- Station 5. Transect from Punta Charagato, Cubagua, 200 m northward down to 2 m water.
- Subst. 1. Intertidal rocks.
- Subst. 2. Eroded rocks, above and below low water mark.
- Subst. 3. *Thalassia* field.
- Subst. 4. From 1 to 2 m water.

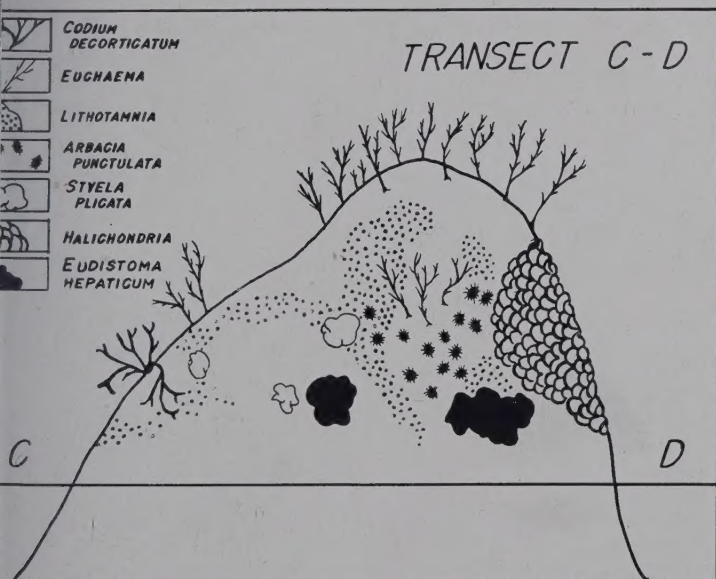


FIGURE 7. Station 1, substation 1. Transect C-D, submerged communities.

ECOLOGY

ECOLOGICAL SURVEY OF ROCKY SHORES

Station 1, Substation 1, is a group of rocks (Fig. 2) that are progressively immersed in a sandy bottom, more or less protected and with little wave action.

Transect A—B (Fig. 3) represents the zonation on the spray and splash zone. On top of the rock, Spray Zone (1) there is a sparse community of *Littorina ziczac*. Its lower limit is the line of H. W. S. In the Splash Zone (2) is a large community of *Balanus trigonus*. The lower section of this zone is occupied by key hole limpets (*Fissurella nimbosa*). In a peculiar case (Fig. 4), there is a concentration of *Littorina ziczac*, forming a line at the lower limit of *Balanus*.

Below this Balanoid Zone the Algal Belt (3) begins. The upper portion is made up of *Ulva fasciata* and *Enteromorpha*, followed by *Hypnea musciformis*. *Laurencia papillosa* is distributed throughout the algal belt.

Below L. W. S. there are communities of *Caulerpa crassifolia* forming patches on the sand.

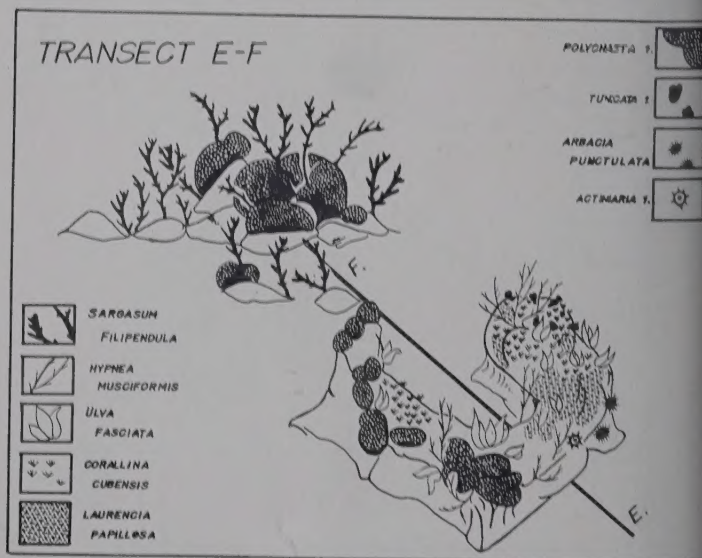


FIGURE 8. Station 1, substation 1. Transect E-F.

a pool on the east side of this transect there is a community of ulous polychaetes, *Onuphis magna* (Fig. 5). The tubes, made up of tritus, sand, small pieces of shells, etc., are exposed on the lower of spring tides (Fig. 6). Temperatures of this pool, as compared to those of the air and a community of *Halichondria*, are given in Table 1.

Transect C—D (Fig. 7) represent the composition of permanently

TABLE 1

COMPARATIVE TEMPERATURES OF AIR, POLYCHAETE POOL AND *Halichondria* COMMUNITY OF STATION 1, SUBST. 1, AUGUST 19, 1956. ($^{\circ}$ C.)

Time	Air	Halich. Comm.	Polych. Pool.
8.15	27.5	26.2	26.5
9.15	26.0	26.2	26.5
10.15	31.0	27.0	28.2
11.15	30.5	27.7	28.5
12.15	31.5	27.3	27.5
13.15	32.0	27.3	27.5
14.15	30.5	26.8	26.8
15.15	27.0	26.2	26.0
16.15	27.5	25.9	25.8
17.15	25.0	25.5	25.2

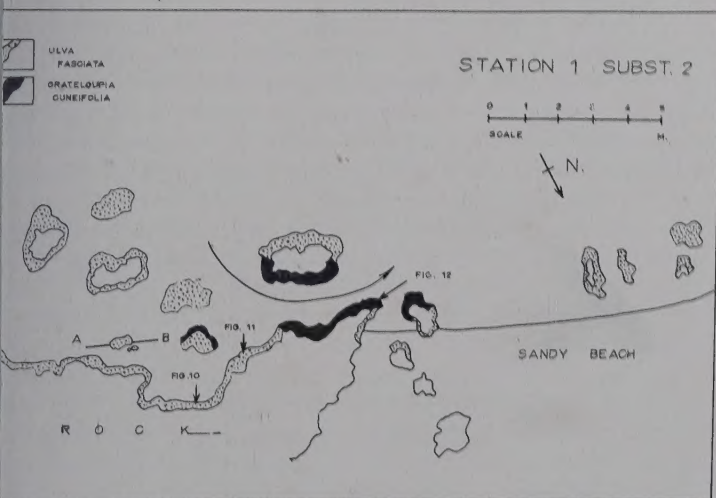


FIGURE 9. Station 1, substation 2. General map showing substitution of *Ulva*.



FIGURE 10. Station 1, substation 2. *Chaetomorpha-Laurencia* association

submerged rocks, with their tops one foot or more below the water. On the tops there were scattered specimens of *Euchaema* (?), wave by the waters. On the sides there were occasional individuals of *Codium decorticatum*. A black sponge of the genus *Halichondria* formed dense communities that served as a refuge for brittle-stars (*Ophiothryx angulata*) and for numerous small crustaceans (*Microphrys bicornutus*, *Epialtus brasiliensis*), and for the young of larger species (*Mithrax forceps*). A colonial tunicate, *Eudistoma hepaticum*, forms chocolate brown patches (Tunicate 1, in Fig. 7), and a solitary ascidian, often tinged red purple, *Styela plicata*, constituted sparse colonies. The small black sea urchin, *Arbacia punctulata*, lived in the crevices of the rock. The denuded surface of the substratum was covered by encrusting *Lythothamnia*.*

The upper part of the transect E—F (Fig. 8) was covered by a community of *Corallina cubensis*—*Laurencia papillosa*, that served as a hiding place for (unidentified) pagurids, small crabs (*Epialtus brasiliensis*, *Microphrys bicornutus*), and young *Mithrax forceps*. There

*Here and elsewhere, the term *Lythothamnia* is used as a general name for all of the encrusting coralline algae.

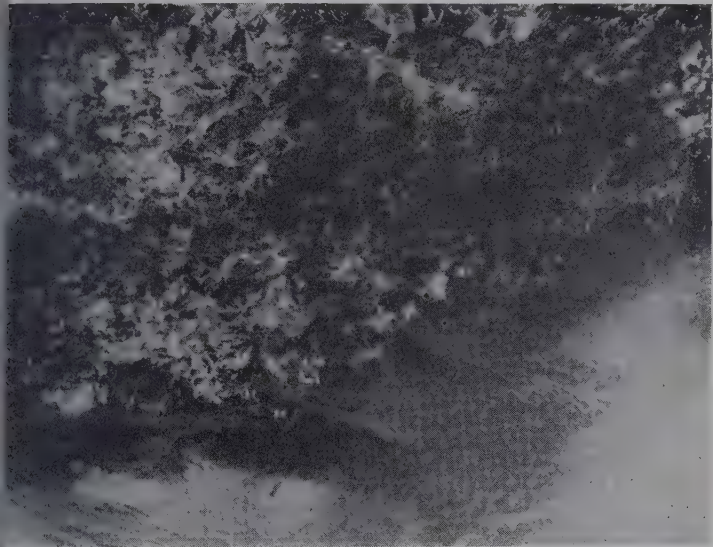


FIGURE 11. Station 1, substation 2. *Ulva-Laurencia* association.

scattered individuals of *Ulva fasciata* and *Hypnea musciformis*. The upper parts of these communities are exposed at L. W. S.

In the crevices of the rock there were several specimens of *Arbacia lixulata*. A single anemone (unidentified, Actiniaria 1), with red polyps on the body was recorded.

In deeper places a reef-building polychaete, *Cirratulus* sp., covered the rocks with a dense formation of black tubes (Polychaete 1), the upper parts of the colonies submerged at L. W. S. Associated with this there was a dense outgrowth of *Sargassum filipendula*. Among these rocks and the rocks the sea urchin *Lytechinus variegatus* was present. Seaward, 15 m, a single specimen of *Luidia senegalensis* was present.

Substation 2 (Fig. 9) was a rocky shore next to Substation 1, in the same seaward direction. It is described with the purpose of giving a detailed position of the algal belt.

Two communities shared the rocks and stones in the upper limit of the algal belt: The association *Ulva fasciata* — *Laurencia papillosa* (Fig. 11), occupied most of the area, but where strong tidal currents were present it was replaced by an association of *Grateloupia cuneata* — *Laurencia papillosa* (Fig. 12). In the general map of the sub-



FIGURE 12. Station 1, substation 2. *Grateloupia-Laurencia* association.

station is shown the action of the currents and the distribution of *Grateloupia*. In most cases this alga was a dark green. In the most protected places *Chaetomorpha media* tended to displace *Ulva* (Fig. 10).

Transect A—B (Fig. 13) shows from above the composition of the algal belt on a rock just below the balanoid zone. The upper part was still occupied by *Balanus trigonus* and *Fissurella nimbosa*. In most exposed places there were communities of *Ulva fasciata* and *Acanthophora spicifera*. A few centimeters below there were *Hypnea musciformis* and *Corallina cubensis*. Occasional specimens of *Padina Vickersiae* were also present.

Reviewing, the following communities were present at these two substations:

- I. *Littorina* Zone (Spray zone), above H. W. S.
- II. Balanoid Zone (Splash zone).
 1. Upper balanoid zone.
 2. Lower balanoid zone, *Balanus-Fissurella* community.
- III. Algal Belt, above L. W. S.

1. *Ulva-Laurencia* association; *Grateloupia-Laurencia* association; *Chaetomorpha-Laurencia* association.
2. *Hypnea-Laurencia* association.
3. *Corallina-Laurencia* association.

V. Infralittoral Zone (Submerged communities) below L. W. S.

1. *Caulerpa crassifolia* consocieties.
2. *Halichondria* consocieties.
3. Polychaete-*Sargassum* association.

ation 2, Substation 1 (Fig. 14) was a group of exposed rocks that stood almost vertically into the sea and were subjected to heavy action.

ansect A—B (Fig. 15) shows the zonation in a section perpendicular to the shore. *Littorina ziczac* occupied the Spray and upper of the Splash zone. The balanoid zone was absent. *Thais haemata floridana* was associated with *Littorina*, at least in the lower of its range.

The algal belt was made up almost exclusively of a Rhodophyceae,

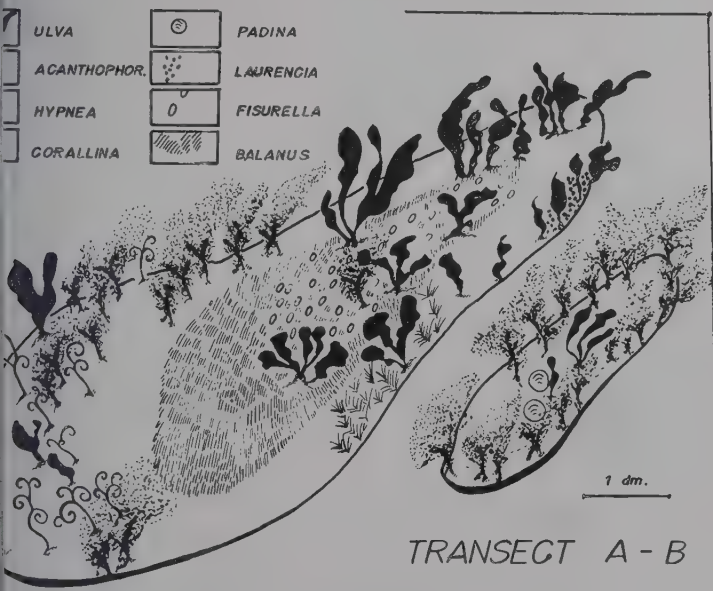


FIGURE 13. Station 1, substation 2. Transect A-B.

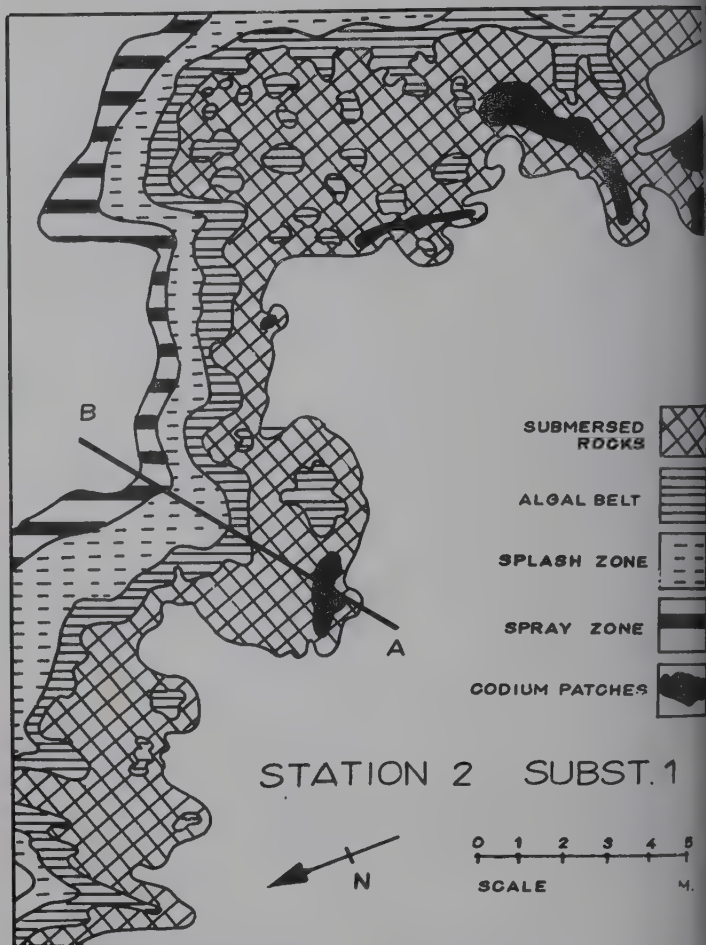


FIGURE 14. Station 2, substation 1. General arrangement of the zones

brown green in color, *Pterocladia* sp. Occasional patches of *Jania* were found in the upper part of the belt.

The rocks down from the algal belt were almost devoid of any algal growth, except for a gigantic *Codium*, that I think must be conspicuous

Codium magnum, described by Dawson (1950), from the coast of Baja California, Mexico. Our plants at this Station attained a size of 1 m. The dichotomies were flat and wide, over 10 cm wide and 1 m long. It is amazing that such a conspicuous plant has never been recorded from the Caribbean. The nearest species is *Codium elongatum* Agardh (to 2 m long) which is certainly different from our

the sand, at a depth of 1 m, there were numerous loose stones, protected a peculiar fauna. The upper surface was dominated by individuals of *Chiton tuberculatus*. A small violet limpet, *Fissurumbosa*, was occasionally found.

Under the stones the fauna consisted usually of two species of brittle stars, *Ophiothryx angulata* and *Ophionereis reticulata*. A small sea slug, *Thyone cognita*, was also present. Gliding underneath the stones was an unidentified turbellarian, fairly abundant.

The rocks and stones from the algal belt down were completely covered by violaceous—pink encrusting *Lythothamnium*. There were a

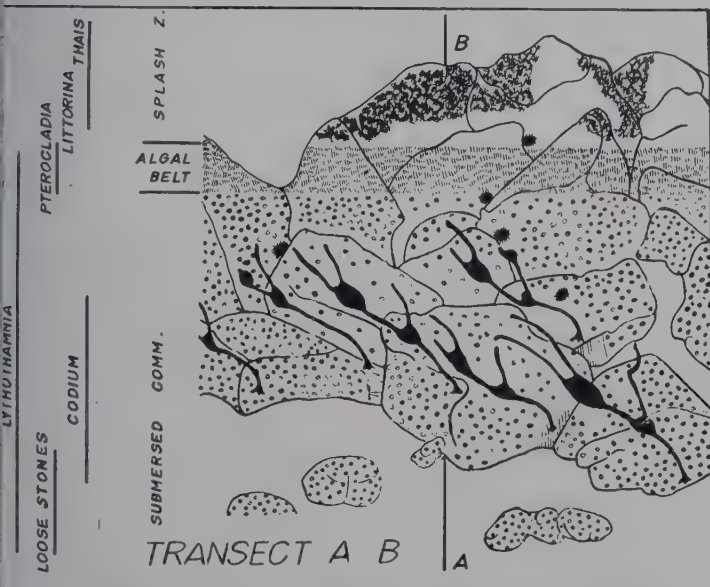


FIGURE 15. Station 2, substation 1. Transect A-B.

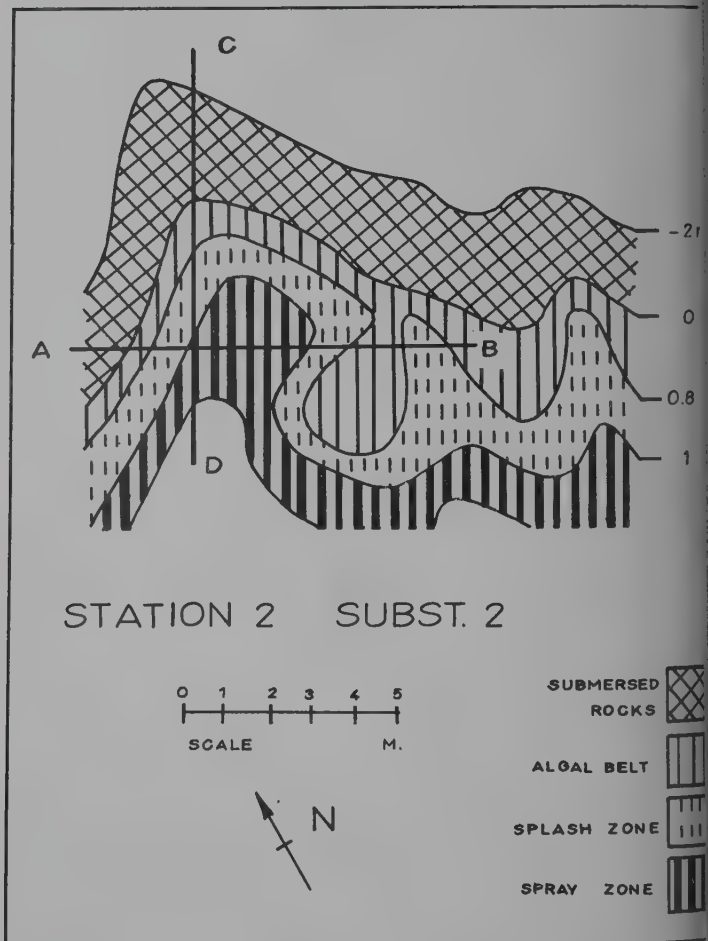


FIGURE 16. Station 2, substation 2. General arrangement of the zones. few *Echinometra lucunter* in the algal belt and on the submerged rocks.

In general, the infralittoral zone was agitated by strong currents that waved the *Codiums* back and forth.

station 2 (Fig. 16) was an unprotected and steep rocky shore, a wave action heavier than in the preceding.

Transect A-B (Fig. 17) is a section parallel to the shore. In the Balanoid zone there were patches of *Balanus trigonus*, and in higher zones, *Tetraclita squamosa*. There were a few communities of *Pterocladia* on the most protected places, but on the surfaces of the rock exposed directly to the sea, there were no algae at all and the rock opened to a sandy bottom at 2 m.

Exploration of the submerged rocks was difficult due to the heavy surf. But, as far as could be seen, algae and invertebrates were almost completely absent. Encrusting *Lythothamnium*, pinkish in color, covered the surfaces, as well as the algal belt, where *Pterocladia* was absent.

Transect C-D (Fig. 17) represents a section perpendicular to the shore. Above the *Littorina* zone, in places completely dried, there were a few specimens of *Tectarius muricatus*. The Spray zone was occupied by *Littorina ziczac* and a few specimens of *Nerita versicolor*. *Nerita peloronta* was present at the lower limits of the zone. In the Splash zone there were patches of *Balanus trigonus*, and *Perna perna* formed small communities in the lower Balanoid zone. *Perna perna* has been recorded from Patagonia to Rio de Janeiro. Our specimens correspond

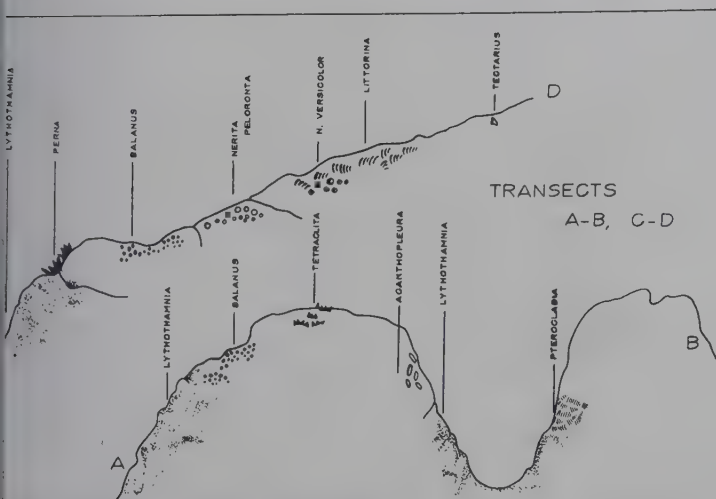


FIGURE 17. Station 2, substation 2. Transects A-B, C-D.

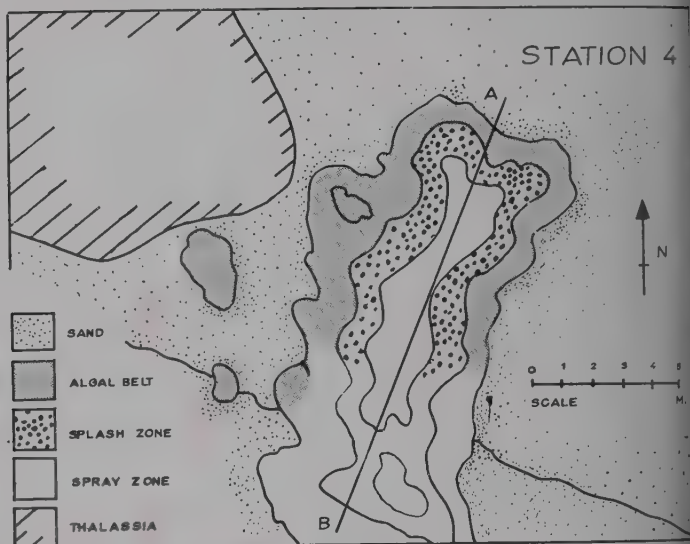


FIGURE 18. Station 4. General arrangements of the zones.

very closely to the description of the species as given by Soot-Rye (1955). But as it has not been recorded elsewhere in the Atlantic north of Rio de Janeiro, it is with doubt that I ascribe my Venezuela specimens to this species.

As stated above, the Algal Belt was absent. *Lythothamnium* covered the place from this level, down.

In general, the communities were numerous in species, but poor in the number of individuals.

Reviewing, the following communities were present at these two substations:

Substation 1,

- I. *Littorina* zone (Spray and, partially, Splash zone).
- II. Algal Belt, *Pterocladia* consociates.
- III. Infralittoral zone.
 1. *Codium* consociates.
 2. Stone surface *Chiton* consociates.
 3. Understones Ophiuroidea association.

ation 2,

- I. Supralittoral zone, *Tectarius* zone.
- II. *Littorina* zone (Spray zone).
- III. Balanoid zone (Splash zone).
 1. Upper Balanoid—*Tetracrita* zone.
 2. Lower *Perna* consociates.
- IV. Algal Belt (occasional) *Pterocladia* consociates.
- V. Infralittoral zone, *Lythothamnium* zone.

ation 4 (Fig. 18) was a group of rocks projecting from a sandy beach in a northward direction, unprotected and with heavy wave action. On the west side there was an extensive *Thalassia* field.

Transect A—B (Fig. 19) represents the main communities in a section perpendicular to the shore. In the crevices of the rock in the Spray zone there was a large community of *Littorina ziczac*. The males, smaller and darker, occupy the higher places and the females, larger and whitish, the lower level. I take for granted that smaller forms

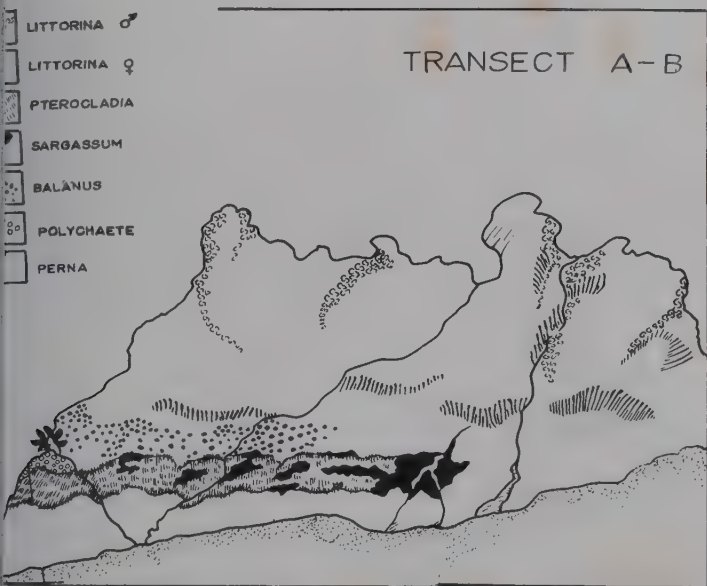


FIGURE 19. Station 4. Transect A-B.

correspond to males, but in fact in the Florida Peninsula, in some localities, three morphological forms may be separated. A Balanoid Zone of *Balanus trigonus* formed the Splash Zone. Below was the Algal Belt with a predominance of *Sargassum filipendula* and *Pterocladia*. In some places *Lythothamnium* substituted for the *Sargassum*. In places most exposed to wave action between the Balanoid Zone and the Algal Belt, there was a community of *Perna perna*. A tubiculous polychaete that formed massive colonies of gray tubes made of sand, substituted in some places for the colonies of *Perna perna*. Some of their empty tubes were inhabited by an errant polychaete, *Nereis bairdii*.

Nerita versicolor, *N. peloronta*, *Thais haemastoma floridana*, *Fissurella nimbosa* and *Tegula lividomaculata* were present in the Balanoid Zone and the Algal Belt.

The rock from the Algal Belt down was covered by *Lythothamnium*. Further details of the Sublittoral Zone could not be worked out because of the heavy surf.

There were four color zones sharply delimited:

The *Littorina* zone was brown-black. The Balanoid Zone was whitish-gray. The tubiculous polychaetes were yellow-gray and the Algal Belt was yellow-brown. In rocky shores not so exposed, the green color of the Algal Belt was due to the presence of *Ulva* as a dominant.

Reviewing, the following communities were present at this Station:

- I. *Littorina* Zone (Spray Zone).
- II. Balanoid Zone (Splash Zone).
 1. Upper Balanoid Zone.
 2. Lower *Perna* consociates, *Nereis* consociates.
- III. Algal Belt, *Pterocladia*-*Sargassum* association.
- IV. Infralittoral Zone, *Lythothamnium* Zone.

GENERAL REMARKS ON ROCKY SHORES

From the preceding analysis it can be concluded that the zonation of our rocky shores fits very well in Stephenson's general scheme. Fig. 2 illustrates the general features as compared with Stephenson (1949).

The *Littorina* Zone was constant and well represented. Almost always it was separated into two forms, that in some cases showed different vertical distribution. This zone may be lower on some occasions.

The Balanoid Zone was almost constant, being absent or incon-

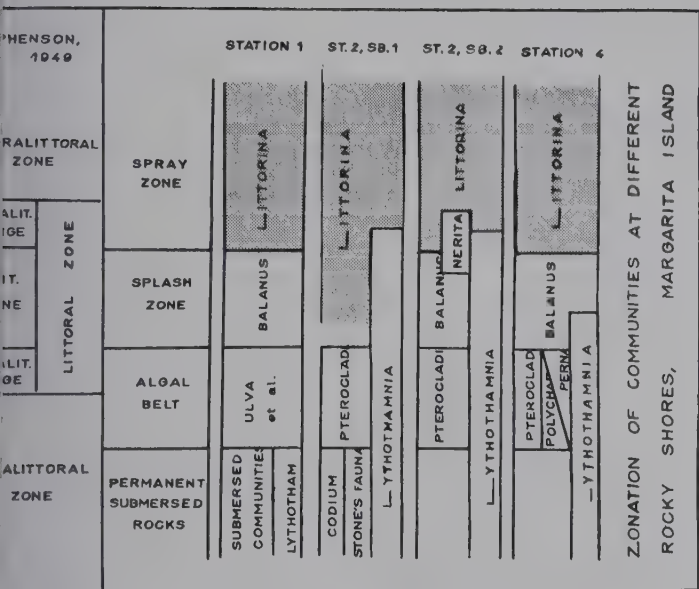


FIGURE 20. General scheme of the rocky shores.

ous only in one case. It may be complicated by the presence of
ellids, polychaetes, etc.

the Algal Belt was constant, but varied greatly in composition ac-
cording to wave exposure. On exposed rocks, *Pterocladia* and *Sar-*
m tended to replace the more delicate *Ulva* association. Even the
position of this *Ulva* community, however, may be altered by tidal
ants, the *Ulva* being replaced by *Grateloupia*.

the *Lythothamnium* level rose in proportion to wave exposure.

the infralittoral communities were more numerous and bulky with
the surf. In places where wave action was strong, the permanently
merged algae tended to disappear, and the fauna, other than flat
pets or chitons, sought refuge under stones.

in general, I believe that the degree of exposure to air determines
the general distribution of zones, but exposure to wave action, together
with other factors, determines the level of zones as well as the presence
and composition of the communities. The presence of certain domi-
nants tends to modify the conditions within the microclima.



FIGURE 21. Station 1, substation 3. Sandy shore.

ECOLOGICAL SURVEY OF SANDY AND MUDDY SHORES

the Open Sandy Shore. Sandy shore communities were investigated at several Stations.

At the east side of Subst. 1, Station 1, there was an open sandy shore. The lower zone, below L. W. S., was inhabited by *Mellita quinquiesperata latiambulacra*, partially buried in the sand. On the line where the water reached the beach, moving with the tide, there was an abundant community of *Emerita brasiliensis*. Next there were a few specimens of *Donax variabilis*, buried 5-10 cm in the sand. Finally there was a dense community of Talitridae, and above this zone, a few specimens of *Ocypode quadratus*.

At Station 1, Substation 3, there were similar communities, whose formation is represented in the general map of the Substation (Fig. 21). *Emerita* was represented by a few specimens. Square no. 1 was 1 m² area and 10 cm deep. Forty-six specimens of *Donax* were counted there. Together with *Donax* there were a few specimens of a second decapod, *Tivela mactroides*. In other sandy shores of Venezuela that had the opportunity of examining, both species were equally abundant on the beaches, burrowing very rapidly as soon as the retreating wave washed the sand, leaving the animal exposed. But in the regions examined in Margarita Island, very few specimens were taken. On one occasion I collected one specimen living on the *Thalassia* field of Station 4, a rather peculiar habitat for this species.

On the upper littoral of this substation, *Ocypode quadratus* was very abundant, but talitrids were scarce.

The sandy shore at the east of Station 4 had a community of *Donax velata*, but other forms were absent or very poorly represented.

At Station 5 the sandy shore possessed, in addition to all the communities mentioned above, an extra belt of Talitridae (*Orchestia?*), living among the seaweeds and *Thalassia* leaves cast upon the shore, forming a continuous band.

Transect A—B (Fig. 22) represents the general arrangement of the communities found in all these shores, but not on one particular shore. Some beaches can possess all of them, a few or none. Dahl (1953) during his brief stay in Venezuela studied a shore (Gañango, near Puerto Cabello), which, by the way, was one much frequented by others. It was rarely that he could find only *Ocypode*, as a dominant form.

Thalassia Formation. Fields of Monocotyledonous plants are a main

feature of sandy bottoms. In tropical waters, *Thalassia testudinum* forms extensive submerged prairies on such bottoms. In the W Indian region, these fields constitute a biocenosis which is a unit in itself and thus can be considered, together with the mangroves, as one of the two Formations of sandy bottoms. The bathymetrical limits of *Thalassia* range from L. W. S. to a few meters deep. On the upper limit of their distribution, the limiting factor is apparently the degree of exposure to wave action.

At Station 1, Substation 3 (Fig. 21), there was an extensive *Thalassia* field. In the general map of this Substation I have tried to represent the conditions of protection that determine the presence of this Formation in such a place.

At the west side of Station 4 and on the sandy bottom of Station 5 (Fig. 26), there were also fields of *Thalassia*. In the shallow regions, there were numerous communities of animals buried in the leaves and rhizomes of the plants. At these three Stations the most common forms were holothurians of the genus *Thyone*, pelecypods such

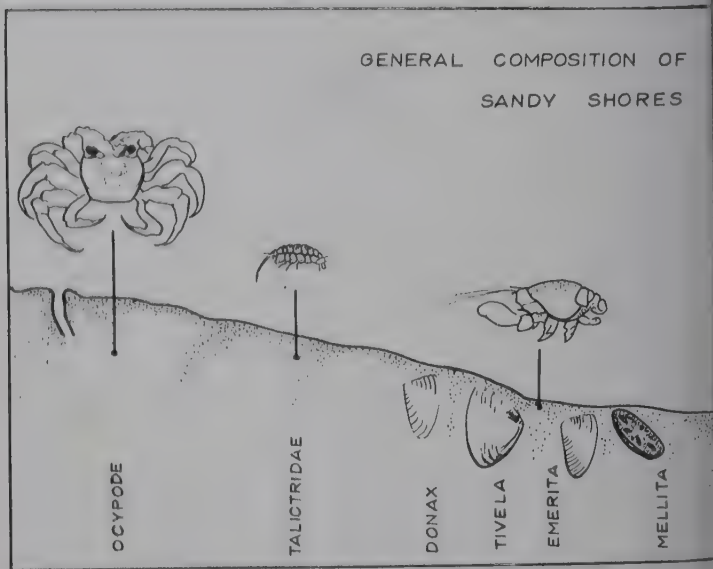


FIGURE 22. General composition of a sandy shore. Transect A-B.

kia orbiculata, *Modiolus tulipus* and others, and a few gastropods including *Cantarus auritula* (?) and *Nitidella* sp. The tips of the leaves serve as a holdfast for several algae, *Colpomenia sinuosa*, *Ulva* and other greens, that move back and forth with every wave.

Deeper water, 0.5 m below L. W. S. and down to 2 m bigger shells such as *Strombus gigas*, *Voluta musica*, *Murex brevisfrons*, *Lascaolaria tulipa*, represent the Gastropoda. *Aplysia protea* was not here, but is common also in various habitats (including bare bottom, rocky bottom, patches of algae, etc.). A huge starfish, *Patiria reticulatus*, is very common. Among the leaves of *Thalassia* on the bare sand, a very common sea urchin, *Lytechinus variegatus*, covered itself with leaves and detritus. This rendered it less conspicuous and, no doubt, also protected it from insolation.

Reviewing, the following communities, then, are typical of sandy bottoms in this area:

I. *Ocypode* Zone.

II. Talitridae Zone.

1. Excavating forms.
2. Forms living upon debris.

III. *Emerita* Zone.

IV. *Mellita* Zone.

V. *Thalassia* Formation.

1. Forms living on the tips of the leaves:
Colpomenia—*Ulva* association.
2. Forms buried within the leaves and roots:
Thyone—Pelecypod association.
3. Forms living on patches of *Thalassia*:
Strombus—*Oreaster* association.

Mangrove Formation and Muddy Shores. When a mangrove community is established on a shore, generally there is a deposit of mud. The mangrove, like the *Thalassia* fields, constitutes a large biocenosis and forms a unit in itself in tropical waters, being in this way a Formation typical of sand-mud bottoms.

Station 3 was a sandy bar that separated the south extremity of Bahía de Las Marites from the open sea. This lagoon was in free communication with the sea through a wide channel lying westward of our Station. The Lagoon had approximately the same salinity as the sea, but its still waters allow a dense growth of mangroves to

form a continuous band on its borders. In the interior of the sea bar there was an extensive shallow pool communicating with lagoon.

During the sampling of communities, six substations were fixed, each one representing a main feature of the Station (Fig. 23).

Substation 1 was a sandy shore on the sea side of the bar. In the intertidal zone there were a few large stones of an old wall and decayed trunk of a palm tree, both serving as a protective habitat for many species. In the absence of any rocky shore nearby, many individuals of several littoral species concentrated here. The stones were overgrown by *Enteromorpha* and *Acanthophora spicifera*. An unidentified species of an errant polychaete lived in the crevices of the palm trunk. An undescribed species of the isopod *Erichsonella*, *Petrolisthes armatus*, the juveniles of *Panopeus occidentalis*, *Pachygrapsus transversus*, *Plagusia depressa*, *Epialtus brasiliensis*, and juveniles of *Marax forceps*, constituted the crustacean fauna of the palm trunk. With the exception of a small white tectibranch, no other Mollusca were present.

The stones were partially covered by *Balanus trigonus*. The rest of the crustacean fauna was made up of *Pachycheles monilifer*, *Petrolisthes armatus*, juveniles of *Panopeus occidentalis*, *P. herbstii*.

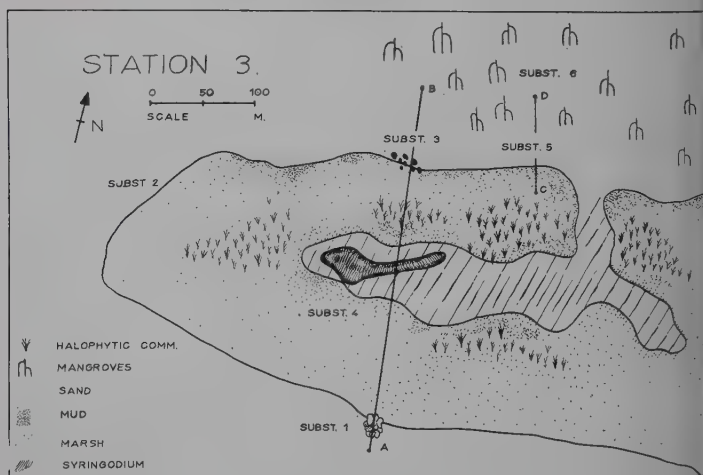


FIGURE 23. Station 3. Main communities.

rax forceps, and *Microphrys bicornutus*, and *Epialtus brasiliensis*. mollusks were present.

Station 2 was a muddy shore on the lagoon side. The bottom was covered by two filamentous chlorophyceae that form extensive patches. A decayed and partially buried mangrove branch served as a holdfast for a solitary but vigorous specimen of *Acanthophora*. Within its rhizoliths there was hidden a numerous fauna. A mimetic caridean shrimp was very abundant, and so well disguised with its brownish color that it was difficult to collect. Other crustaceans present were *Petrolisthes* sp., juvenile *Panopeus occidentalis*, and *P. bermudensis*, and *Microphrys bicornutus*. This fauna is not peculiar to this community. It is the same found in the protected biotopes of Station 1. Its abundance here may be explained in the same way as that in the Station 1.

Station 3 was a group of flat stones on the intertidal areas of the lagoon shore. The fauna consisted of *Cerithium eburneum*, *Cerithium costata*, and very small unidentified pagurids forming very small patches on the surfaces of the stones. A few specimens of *Stomatopoda patula* were scattered through the area. A single specimen of *Stomatopoda muricatus* was present on the upper stones, in a place completely dry.

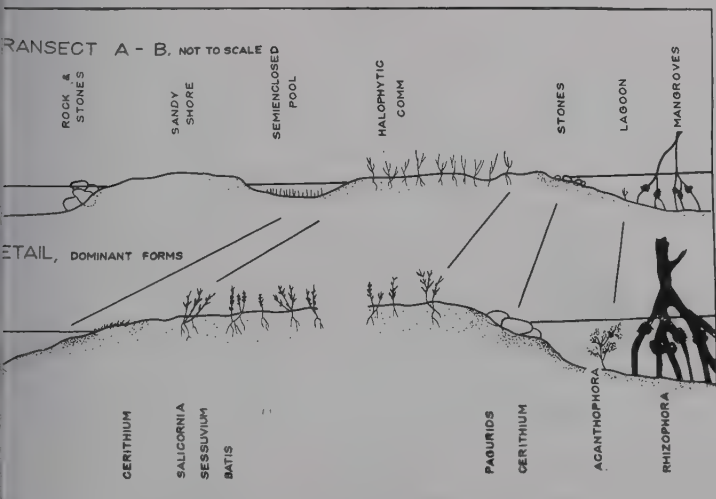


FIGURE 24. Station 3. Transect A-B.

Substation 4 was a shallow pool that covered most of the bar, was in free communication with the lagoon waters. In some places bottom was covered by a monocotyledonous plant, *Siringodium forme*.

On a muddy section on the west side, periodically inundated by tides, there was a crowded community of *Cerithium eburneum*, forming a continuous band of several square meters of animals very close together. There were three specimens of *Littorina angulifera* in same sector.

The pool serves as a nursery ground to hundreds of young mullets. The temperature was higher in these waters than in the rest. On Aug 23 at 14.30 hours we recorded the following temperatures: Air: 29°C, Open shore (Subst. 1): 30.4, Pool (Subst. 4): 32.2°C.

The sandy sections outside the pool were covered by halophyte communities of *Batis maritima*, *Sessuvium portulacastrum*, and *Sarcocornia* sp. The general composition is represented in Transect A (Fig. 24).

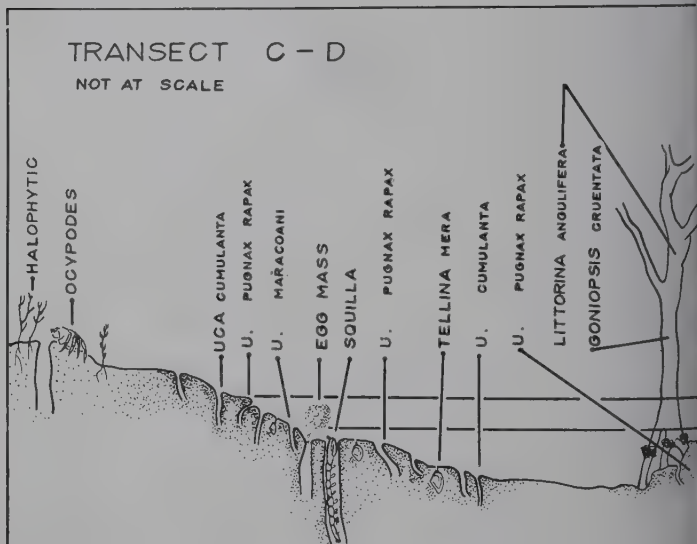


FIGURE 25. Station 3. Transect C-D.

cypode quadratus was on the upper part of the shore which included these halophytic communities.

Substation 5 was a muddy shore in the lagoon. The general composition is exposed in Transect C—D. (Fig. 25). The fauna comprised the species of *Uca* that burrowed in the mud: *U. cumulanta* and *U. pugnax*, very abundant, and *U. maracoani*, very rare. A white cypod, *Tellina mera*, lived buried in the mud. In deeper water (1 foot at L. W. S.), lived a *Squilla dubia*, very large and robust, 15 cm in length. Their holes sometimes were covered by transparent bags, 10 cm long, with eggs in the jelly walls. These egg masses probably belong to a polychaete that could not be detected. From the line of low water to the line of high water four squares were explored, one one meter square and 20 cm deep. The results are shown in Table 2.

TABLE 2

ANIMALS PER SQUARE METER IN A SECTION OF A MUDDY SHORE,
STATION 3, SUBSTATION 5. UPPER LIMIT INDICATES H. W. S.,
LOWER LIMIT L. W. S.

Square	<i>U. cumulanta</i>	<i>U. pugnax</i> <i>rapax</i>	<i>U. maracoani</i>	<i>Tellina</i>
I	17	31	0	0
II	41	0	2	3
III	29	5	0	1
IV	18	0	0	1

In some other places of the Venezuelan coast, I have found some relation between grain-size and the presence of the different species of *Uca*. Perhaps this will account for the irregular distribution of the species here.

Substation 5 was a community of mangroves. The main species was *Acanthophora*. But there were also scattered specimens of *Conocarpus erectus*. The bottom was muddy and almost devoid of life with the exception of a red starfish, *Echinaster guildingi*, which was fairly common, occasional specimens of *Acanthophora spicifera*, and a few rhizomes of *Caulerpa racemosa* f. *occidentalis*.

On the roots of the mangroves, between low and high water marks, there were masses of a very crowded community, with several forms peculiar to these habitats. The stroma of the community was formed by the oyster *Crassostrea* sp., the red sponge *Tedania ignis*, the black tunicate *Ascidia nigra*, and the translucent colonial *Ecteinascidia turrita*. This mass of organisms gave protection to a very rich fauna of

errant polychaetes, carideans, and other crustaceans. The isopod *Coralana quadricornis* was very abundant in the crevices. Other crustaceans present were: *Petrolisthes armatus*, *Aratus pisonii*, *Microphallus bicornutus*, and young *Mithrax forceps*. On the mud along the mangrove groves, in places exposed at low water, there were a few specimens of *Uca cumulanta*. Isolated on the submerged roots was the alcyonid *Telesto rupicola*.

The branches on the upper part were dominated by a red coral, *Goniopsis cruentata*. *Littorina angulifera* was found climbing the branches several meters above H. W. S.

Summarizing our results, the following communities were represented at this station:

- I. Sandy shore.
 1. Protective habitats of stones and wood.
 2. The *Ocypode* Zone.
 3. The halophytic zone, *Sessuvium-Batis-Salicornia* association.
- II. Muddy shore.
 1. The *Uca-Tellina* association.
 2. The *Syringodium* consociation.
 3. The *Squilla*-polychaete (?) association.
- III. Mangrove Formation.
 1. *Acanthophora* consociation.
 2. *Crassostrea-Tedania-Ascidia* association.
 3. The aerial zone (*Littorina-Goniopsis* communities).

GENERAL REMARKS ON SANDY AND MUDDY SHORES

Dahl in a recent study (1953) has tried to apply to sandy shores the same criterion that Stephenson applied to rocky shores. His zones are: (1) The subterrestrial fringe (Talitrid-ocypodid belt); (2) Midlittoral zone (*Cirolana* belt); (3) The sublittoral fringe (rich and varied fauna). Having studied zones in cold, temperate, and tropical waters (Venezuela), he stated that in the tropics the amphipods are the dominant crustaceans, and are replaced by the Decapoda in temperate areas.

Gauld and Buchanan (1956) in a study of the sandy beaches of the Gold Coast, denied that Dahl's idea was of universal applicability, and noted that *Exocirolana* and *Ocypode* occupy the same niches in the area. Amphipods were also present, although these were tropical species. They suggest the convenience of adding two more zones for the

als, the *Donax* and the *Nerine* zones. The beaches of the Gold include two types: One steep, of coarse sand, with no fauna than *Ocypode hippeus* near H. W. M., and another of finer sand flatter, with several zones.

In our area we observed that the composition of sandy shores varies both in number of species and of individuals, according to factors that were not apparent.

The sand flats above H. W. S. are usually colonized by halophytic communities.

Muddy shores also have a fauna of pelecypods and crustaceans, but the species are quite different from those in the sand. There is a predominance of crabs (*Uca*) and the horizontal zones are not so well defined.

In general, the communities of tropical muddy shores are very little known. Crane has published, together with a taxonomic treatment, observations on the behavior of *Uca* in the tropics. One of her papers deals with the Venezuelan species (1943).

More or less protected sandy shores in the tropics exhibit two main formations: Mangrove where there is a predominance of mud, and *Posidonia* where there is more clear sand.

Penhale (1947) has analyzed the "restingas" of Brazil. He found the following communities within the mangrove formation, in a shoreward direction: (1) *Rhizophoretum manglei*; (2) *Avicennietum tomentosae*; and (3) *Laguncularietum racemosae*. This stratification is apparently due to the duration of inundation and nature of the substratum. Each of these associations is selective for the species of *Uca* inhabiting the mud among the roots. This outstanding contribution has been in considering the water communities, a procedure unfortunately not always followed by most land ecologists.

As far as I know, no general study has been published on the Thalassia formation of tropical waters. The vegetation of *Posidonia*, *Cypraea*, and *Zostera* have been studied by Molinier and Picard (1922) along in the Mediterranean coast of France, in its aspect of succession and climax.

ECOLOGICAL SURVEY OF THE CORAL FORMATION

Station 5 in the present survey represented a similar area to that studied by Voss and Voss (1955) in the Florida Keys. No attempt has been made to determine communities in this Station, as our present

knowledge of these formations is not sufficient to permit a so analysis. Only the main zone will be characterized.

Station 5 was a transect from Punta Charagato, Cubagua, 20 in a northward direction to a depth of 2 m of water. The area incl a very eroded rock, sloping down to below low water, and a sa beach with a *Thalassia* field, (Fig. 26).

Littorina ziczac occupied its characteristic place in the spray z together with occasional specimens of *Tectarius muricatus*. Downv in the splash zone there was a typical community of *Balanus*. *N versicolor* and *Nerita peloronta* were also present here. A very ac crab, *Grapsus grapsus*, lived among these rocks.

Near the limit of L. W. S., the eroded rock presented many cav inhabited by *Echinometra lucunter*. *Eucidaris tribuloides* was occasionally found. The algal belt was, in general, poor, and inclu such forms as *Caulerpa racemosa* f. *clavifera*, *Padina Vickersiae*, *Laurencia papillosa*. The intertidal molluscan fauna was represen by *Fissurella nimbose*, *Diodora* sp., *Livona pica*, and *Thais hae stoma floridana*.

At L. W. S. on a *Thalassia* field, which is described elsewhere in paper, the presence was noted of *Strombus gigas*, *Oreaster reticula* and *Lytechinus variegatus*, very abundant (*Strombus* more than

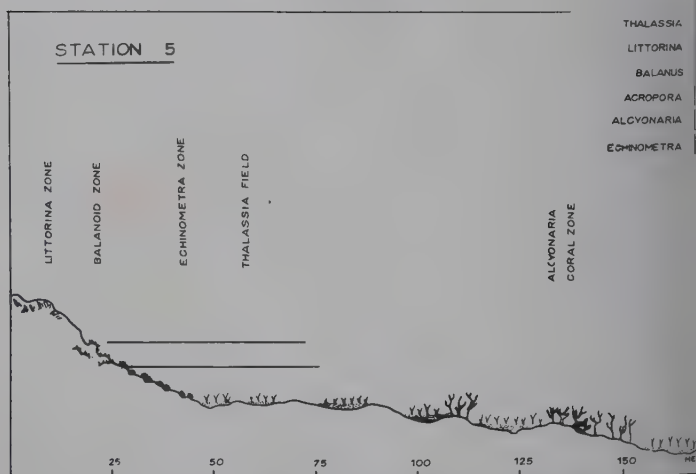


FIGURE 26. Station 5. Transect showing general arrangement of the zones

sq. m) lying on the *Thalassia* bed from 0.5 m down to an un-
 dermined depth.

In places 1 m or more below L. W. S., the rock was dominated by a
 bed of Alcyonaria-coral. *Pterogorgia acerosa*, *Plexaurella kunzei* and
Porites muricata were the main forms of Alcyonaria. The false coral,
Alcyonaria alcicornis, was frequently found growing on dead alcyo-
 naria skeletons. Among the true corals were *Acropora cervicornis*,
Acropora palmata, and species of *Porites* and *Meandrina*, not forming a true
 bed, but scattered on the bottom. A very conspicuous sponge was
Eciospongia vesparia. Other forms of Porifera have not been identi-
 fied. *Arca zebra* and *Chama macerophylla* were found living on the
 bed of corals. The crustaceans of this zone include *Pachycheles monili-*
Callinectes ornatus, and *Chlorodiella longimana*. The starfish
Linaster echinophorus, the brittle stars *Ophiactis savigni*, *Ophiothrix*
edwardsi, *Ophiocoma echinata*, *O. riesii*, and *Ophioderma brevicauda*,
 the sea cucumbers, *Pentacta pygmaea* and *Thyone* sp., formed the
 benthic fauna of the zone.

GENERAL REMARKS ON THE CORAL FORMATION

Coral formations are pantropical communities, typical of rocky
 bottoms.

There are only two papers that deal with the subject in the Carib-
 bean in a broad sense. In their study of the Florida Keys, Stephenson
 and Stephenson (1950) have described the characteristic "reef flat."
 They distinguish four color zones, the white, gray and black on the
 sublittoral fringe, and the yellow on the midlittoral.

In a recent paper Voss and Voss (1955) have given an excellent
 description of Soldier Key in the same area. These authors distinguish
 four zones on the lower platform and reef flat: The *Echinometra* zone,
Porites-Coralline zone, the *Thalassia* zone, and the Alcyonaria
 zone.

In our area, the following zones can be distinguished:

- (1) *Littorina* zone.
- (2) Balanoid zone.
- (3) *Echinometra* zone.
- (4) *Thalassia* zone.
- (5) Alcyonaria—coral zone.

We could not separate a *Porites* zone as did Voss and Voss. The lower

limits for *Thalassia* cannot be fixed at present. But in general Alcyonaria zone could be considered as a typical formation of rock bottoms, equivalent to the Formations of *Thalassia* and mangroves the sandy bottoms.

CONCLUSIONS

In the preceding pages I have analyzed the composition and arrangement of the littoral and sublittoral communities in a representative area of the Caribbean. Consideration of physical factors has been limited to substratum, degree of exposure to air, relative exposure to wave action and tidal currents. I am well aware of the descriptive nature of the present contribution.

In the West Indian area we have detailed data only from the Miami area, where The Marine Laboratory has operated for several years. Next in completeness of knowledge is the area of Sao Paulo. Also in Puerto Rico, the U. S. Fish Commission and the New York Academy of Sciences had carried out a careful study of the fauna. For the rest of the Caribbean taxonomic knowledge and oceanographic data are very scarce.

The question may be raised whether the West Indies forms a natural zoogeographical province or not. I hope that the present paper may contribute to the solution of this problem.

The following factors have to be considered:

1. If we compare our list of species with the data we have from the Caribbean Islands, Florida and Brazil, we see that most species have a continuous range through the area. This range extends roughly from Cape Canaveral (Florida) to Rio de Janeiro (Brazil). This is not the place to discuss the taxonomy of algae and invertebrate through the Caribbean. However, we can reach this conclusion by comparing works such as the reports of the New York Academy of Sciences on Puerto Rico, the studies on Brachyura by Mary Rathbun and the records of mollusks of the Western Atlantic published in Johnsonia.

There are several conspicuous exceptions. One of them is *Livona pica*. We do not know with certainty the causes of its irregular distribution of this gastropod, but we may guess that its lability to slight changes of temperature may account for it. Smith *et al.* (1950) have given for the Miami inshore water temperature range in winter of 14°C, with the extreme low

- 18.25. This condition is not usually found in Bahamian waters, the northern limit of *Livona pica*.
2. We do not have at present enough biological data on growth rate, size, abundance and constancy of dominants and allied species, but at least the general composition of the communities in the central Caribbean, as represented by our analysis, can be compared with marginal areas such as Rio de Janeiro (de Oliveira, 1947, Dansereau, 1947) and Florida (Stephenson and Stephenson, 1950). In the case of Rio de Janeiro there are some communities whose composition correspond closely with ours, i.e. the mytiliforms (*Perna* ?) of surf beaten rocks. In the Florida area it is not so apparent because of the peculiar nature of the substratum in many places, i.e. Florida limestone built up by a Pleistocene coral reef. But in some places near Miami, such as Bear Cut, many communities have the same composition, maybe the same role. This is true of sponges, tunicates, (*Styella*, for instance) and polychaetes.
3. The Stephenson scheme shows the same peculiarities of zonation in the marginal areas mentioned above and in our area. So, the *Littorina* zone in Florida is represented by *Littorina ziczac*, which tends to be segregated in two or three forms (sexual dimorphism?). Some features present a curious similarity. For instance, compare the zonation of colors in our Station 4 with that of Stephenson's in the Florida Keys. However, certain peculiarities of our algal belt are not so distinct in other areas. Replacement of the *Ulva* communities by *Pterocladia* is not so apparent in Florida, and we do not have precise data from Brazil.
4. The most prominent feature in common with the other areas is the presence of three extensive formations, namely *Thalassia* and mangrove on the sandy bottoms and Coral-Alcyonaria on the hard substratum.
- Thalassia*. We do not have enough data regarding its distribution in Brazil. From Florida we have the map of distribution compiled by Voss and Voss (1955). From our personal observations we have noted that the composition of this formation regarding presence of epiphytes and general conditions of protection is similar in Margarita Island and on the Florida coast. Its northern limit (Voss and Voss 1955) is Miami, but the

southern limit in Brazil is unknown.

Mangrove. The analysis by Davis (1940) for Florida, and D. Sereau (1947) for the "restingas" of Rio de Janeiro correspond quite closely, over all, in the zonation of the various species of mangrove. Unfortunately they do not insist on the composition of the very interesting ring of sessile forms present on the rocks below the water line. Apparently *Ostrea* and *Crassostrea* are common forms in both areas (Gunther, 1951). The major differences through the West Indies regarding this formation are the different species of *Uca*. Venezuela has two forms not present in other areas (Crane, 1943), *U. cumulanta* and *U. multifida*. A third species is present in Brazil and Venezuela, but not in Florida, *U. maracoani*. And finally one species is common in the three areas, *U. pugnax rapax*. In other parts of Venezuela, i.e. the estuary of Maracaibo, I have found another species, *U. leptodactyla*, not cited in the study by Crane, but recorded by Rathbun (1918) from Florida to Santos, Brazil.

Coral—Alcyonaria. The corals in the West Indies extend from Florida to Recife, Brazil. The characteristic features of this formation in Florida have been given by Voss and Voss (1955). They correspond, as has been shown, quite closely with the formation of Alcyonaria-coral. Voss stated (personal communication) that the *Porites* zone may be absent or obscured in some places in the Florida Keys as it was in our Station 5. We do not have an analysis of this formation southward, but many forms apparently characteristic of such places have been recorded at different localities in Brazil, up to Rio de Janeiro.

In general we may consider the West Indies as a natural biogeographical province extending along the East Coast of the American continent, between 25-30°N and 25-30°S. Its northern boundary would be located on the east side of the Florida peninsula between Cape Cañaveral and Key West, and its southern around Rio de Janeiro, Brazil. But it is only in its general traits that this area can be considered as a biogeographical province. The fact of being tropical, with its bearings on the metabolism of organisms together with many complicated geographical factors contribute to create a diversity of flora and fauna. The Florida current and the two gigantic estuaries of the Orinoco and the Amazon by themselves may account for important changes in the regularity of distribution of organisms. At present we

w only facts in the Florida area. The other areas are a gigantic task in the future.

APPENDIX

TAXONOMIC TREATMENT OF THE FAUNA AND FLORA OF MARGARITA ISLAND INVERTEBRATES

The fauna of Margarita Island is typically that of the West Indian geographical Province.

The following list is not in any way an attempt to give an elaborated catalog of the island, which is beyond the scope of the present paper. Such a study could only be accomplished by the work of specialists over a period of years. Such work has not previously been attempted, and even the general fauna of the Caribbean is not yet known. For this reason, only the dominant and most common species are listed below.

Special difficulty has been encountered in the treatment of some of the poorly known groups. In the sponges only two species are listed. At present, a taxonomic study of this group in the Caribbean is very difficult. Moreover, field identifications in this group are difficult since the most common species can be identified without the aid of a specialist.

No attempt was made to identify sea anemones. Only very common species of tubicolous polychaetes and non-colonial tunicates are given. When there was an absolute need to refer to them, a provisional name was given.

When there was no certainty regarding the identity of a species, a question mark is placed after the name.

A good taxonomic treatment of the invertebrates of this area is very much needed.

PORIFERA (det. R. Work)

Schondria ? sp. Station 1, Subst. 1.

Amphipora ignis (Duchassaing & Michelotti). Station 3, Subst. 6 on mangrove roots.

CNIDARIA HYDROZOA

Alcyonaria alcicornis L. Station 5, Subst. 4, on skeletons of dead

Alcyonarians. El Morro, dredged on rock.
Sertularia westindica (Stechow). Station 1, Subst. 1, on Corall
 black sponge community.

ALCYONARIA

(det. Dr. Gilbert Voss)

Telesto rupicola (F. Müller). Station 3, Subst. 6, on mangrove ro
Pterogorgia acerosa (Pallas). Station 5, Subst. 4.
Plexaurella kunzei (Kukenthal). Station 5, Subst. 4.
Muricea muricata (Pallas). Station 5, Subst. 4.

MADREPORARIA

Acropora cervicornis (Lamarck). Station 5, Subst. 4.
Acropora palmata (Lamarck). Station 5, Subst. 4.
Porites sp. Station 5, Subst. 4.
Meandrina sp. Station 5, Subst. 4.

ANNELIDA POLYCHAETA

Nereis bairdii Webster. Station 1.
Onuphis magna Andrews. Station 1, Subst. 1.
Cirratulus sp. (G. Voss ident.) Station 1, Subst. 1.

ARTHROPODA

CRUSTACEA CIRRIPIEDIA

Tetraclita squamosa stalactifera (Lamarck). Station 2, Subst. 2.
Balanus trigonus Darwin. Station 1, Subst. 1, black sponge co
 munity. Station 3, Subst. 1, on submerged stones.

ISOPODA

Exocoralana quadricornis Hansen. Station 3, Subst. 6, on mangro
 roots.
Erichsonella sp. Station 3, Subst. 1, on decayed submerged wo
 Very possibly, an undescribed species.

STOMATOPODA

(det. R. Manning)

Squilla dubia (Milne Edwards). Station 3, Subst. 5.

ANOMURA

Pachycheles monilifer (Dana). Station 1, Subst. 1. Station 3, Subst.
 stones. Station 5, Subst. 4.

olisthes armatus (Gibbes). Station 3, Subst. 1, wood, stones. Station 3, Subst. 2, *Acanthophora*. Station 3, Subst. 6, on mangrove roots.

erita brasiliensis. Station 1, in sandy beaches.

BRACHYURA

inectes ornatus Ordway. Station 5, Subst. 4.

eractea ceratopus (Stimpson). Station 4.

opeus occidentalis Saussure. Station 3, Subst. 1, Station 3, Subst. 2.

opeus bermudensis Benedict & Rathbun. Station 1, Subst. 4. Station 3, Subst. 2.

opeus herbstii Milne Edwards. Station 1, Subst. 1. Station 3, Subst. 1, stones.

mnus reticulatus Stimpson. Station 1, Subst. 1.

ythium limosum (Say). Station 3, Subst. 5.

prodiella longimana Milne Edwards, Station 5, Subst. 4.

phia gonagra (Fabricius). Station 1, Subst. 3.

iotheres sp. La Restinga, in oysters.

psus grapsus (L.). Station 1, Subst. 4. Station 5, Subst. 1.

tus pisonii (Milne Edwards). Station 3, Subst. 6, on mangrove roots.

hygrapsus transversus (Gibbes). Station 1, Subst. 5. Station 3, Subst. 1, wood.

hygrapsus gracilis Saussure. La Restinga.

tiopsis cruentata (Latreille). Station 3, Subst. 6, on branches of mangrove.

gus depressa (Fabricius). Station 1, Subst. 4. Station 3, Subst. 1, wood.

pode quadratus Fabricius. Station 5, on sandy beach.

maracoani (Latreille). Station 3, Subst. 5.

cumulanta Crane. Station 3, Subst. 5. Station 3, Subst. 6, mud within mangrove's roots.

pugnax rapax Smith. Station 3, Subst. 5.

erophrys bicornutus (Latreille). Station 1, Subst. 1, black sponge community. Station 3, Subst. 1, stones. Station 3, Subst. 3, *Acanthophora*. Station 3, Subst. 6, on mangrove roots.

altus brasiliensis Dana. Station 1, Subst. 1, black sponge community. Station 1, Subst. 1, on *Corallina*. Station 3, Subst. 1, stones. Station 3, Subst. 2, wood.

Mithrax forceps (Milne Edwards). Station 1, Subst. 1, Station 3, Subst. 6, on mangrove roots. Station 3, Subst. 1, wood, stones.

Mithrax pilosus Rathbun. Station 1, Subst. 4.

MOLLUSCA AMPHINEURA

Chiton tuberculatus L. Station 1, Subst. 3. Station 2, Subst. 1, on submerged stones.

Chiton marmoratus Gmelin. Station 1, Subst. 5.

Acanthopleura granulata Gmelin. Station 1, Subst. 5. Station 2, Subst. 2.

GASTROPODA

Aplysia protea Rang. Station 1, Subst. 1. Station 1, Subst. 3. Station 5, Subst. 4.

Diodora sp. Station 5, Subst. 2, stones.

Fissurella nimbosa L. (det. G. Voss) Station 1, Subst. 1. Station 2, Subst. 2, stones.

Fissurella (Cremides) angusta Gmelin. (det. G. Voss) Station 2, Subst. 1, stones.

Livona pica L. Station 5, Subst. 2.

Tegula lividomaculata. Station 1, Subst. 3, Thalassia. Station 1, Subst. 5. Station 2, Subst. 1, submerged stones.

Astraea americana Gmelin. Station 1, Subst. 5.

Nerita versicolor Gmelin. Station 2, Subst. 2. Station 4, Subst. 2.

Nerita peloronta L. Station 2, Subst. 2. Station 5, Subst. 2. Station 1, Subst. 5.

Littorina ziczac Gmelin. Station 1, Subst. 1. Station 1, Subst. 2. Station 1, Subst. 5. Station 2, Subst. 2. Station 4, Subst. 1.

Littorina angulifera Lamarck. Station 3, Subst. 4. Station 3, Subst. 1, in branches of mangrove.

Tectarius muricatus L. Station 2, Subst. 2. Station 3, Subst. 3. Station 5, Subst. 1.

Cerithidea costata da Costa. Station 3, Subst. 2, Station 3, Subst. 4.

Cerithium eburneum Brugiere. Station 3, Subst. 2. Station 3, Subst. 1.

Strombus gigas L. Station 5, Subst. 3.

Murex brevifrons Lamarck. Station 5, Subst. 4.

Purpura patula L. Station 1, Subst. 2. Station 3, Subst. 3. Station 5, Subst. 1.

Thais haemastoma floridana Conrad. Station 1, Subst. 3. Station 2, Subst. 1, wood. Station 4, Subst. 2.

- Mella* sp. (det. G. Voss). Station 1, Subst. 3, *Thalassia*.
Violaria tulipa L. Station 5, Subst. 3.
V. musica L. Station 5, Subst. 3.
Tharusa auritula L. ? (det. G. Voss) Station 1, Subst. 5, Station 1, Subst. 3, *Thalassia*.
Limulus coffeus L. Station 3, 4 dead specimens buried in mud, Subst. 5.

PELECYPODA

- Mytilus edulis* sp. Station 3, Subst. 6.
Modiolus modiolus L. Station 3, Subst. 1, wood. Station 3, Subst. 6, mangrove roots.
Cardium perna (L.) Station 4. Station 2, Subst. 2.
Chiodontes sp. Station 1, Subst. 5.
Cardium mactroides Born. Station 4.
Cardium mera Say ? Station 3, Subst. 5.
Cardium variabilis Say. Station 1, Subst. 3.
Cardium macerophylla Gmelin. Station 5, Subst. 4.
Cardium orbiculata Montagu. Station 5, Subst. 3.
Cardium occidentale Philippi. Station 5, Subst. 3.

ECHINODERMATA ASTEROIDEA

- Aster senegalensis* (Lamarck). Station 1, Subst. 1.
Aster reticulatus (L.) Station 5, Subst. 4.
Aster guildingi Gray. Station 3, Subst. 6.
Aster braziliensis Müller & Troschel. Station 2, Subst. 1.
Aster echinophorus (Lamarck) Station 5, Subst. 4.

OPHIUROIDEA

- (det. Dr. Gilbert Voss)
Ophiura savignyi (Müller & Troschel). Station 5, Subst. 4.
Ophiura angulata (Say). Station 1, Subst. 1. Station 1, Subst. 3. Station 2, Subst. 1. Station 3, Subst. 6.
Ophiura oerstedii Lütken. Station 5, Subst. 4.
Ophiura onereis reticulata (Say). Station 2, Subst. 1.
Ophiura ocoma echinata (Lamarck). Station 5, Subst. 4.
Ophiura ocoma riisei Lütken. Station 5, Subst. 4.
Ophiura ocoma brevicauda Lütken. Station 5, Subst. 4.

ECHINOIDEA

- Echinocardium tribuloides* (Lamarck). Station 5, Subst. 2.

Diadema antillarum (Philippi). Station 5, Subst. 2.

Arbacia punctulata (Lamarck). Station 1, Subst. 1. Station 1, Subst. 2. Station 1, Subst. 3. Station 2, Subst. 1.

Lytechinus variegatus (Leske). Station 1, Subst. 1. Station 2, Subst. 1. Station 5, Subst. 4.

Echinometra lucunter (L.) Station 1, Subst. 1. Station 1, Subst. 2. Station 1, Subst. 5. Station 5, Subst. 3.

Clypeaster subdepressus (Gray). Station 3.

Mellita quinquiesperforata latiambulacra H. L. Clark. Station 1, sandy beaches.

HOLOTHUROIDEA

Thyone cognita Lampert. Station 2, Subst. 1, submerged stones.

Thyone sp. Station 1, Subst. 3, *Thalassia*. Station 5, Subst. 4.

Pentacta pygmaea (Theel). Station 5, Subst. 4.

CHORDATA ASCIDIACEA

Clavelina oblonga Herdman. El Morro, Porlamar.

Ascidia nigra (Savigny). Station 3, Subst. 6.

Styela plicata (Lesueur) El Morro, Porlamar.

Ecteinascidia turbinata (Herdman). Station 3, Subst. 6.

Eudistoma hepaticum (Van Name) (Voss ident.) Station 1, Subst. 1.

MARINE PLANTS

The algae of the Caribbean have been treated by Taylor (1921) and Børgeesen (1913-1920). Recently, Taylor (1942) has reported on the algae of the Venezuelan coast in the collections of the Allou Hancock Foundation. But the problems of many of our forms are not definitely settled.

In the following list are mentioned only the species that were used in the analysis of the communities. In this case, as in the case of the invertebrates, the list can not be considered as a regional floral study.

Encrusting algae were not identified. At present there are only one or two specialists in the world capable of such a task. These algae are referred to in the following pages under the general name of *Lythamnia*.

CHOLROPHYCEAE

Chaetomorpha media (C. Agardh) Kuntzing. Station 1, Subst. 2.

Enteromorpha sp. Station 1, Subst. 1.

Ulva fasciata Delille. Station 1, Subst. 1, 2, 3, Station 4.

ium decorticatum (Woodward) Howe. Station 1, Subst. 1, 4.
ation 4.

ium magnum Dawson. Station 2, Subst. 1.

terpa racemosa J. Ag. f. *clavifera* (Turner) Weber van Bosse.
ation 1, Subst. 4. Station 5, Subst. 2.

terpa racemosa J. Ag. f. *occidentalis*. Station 3, Subst. 6.

terpa crassifolia (C. Agardh) J. Agardh. Station 1, Subst. 1.

PHAEOPHYCEAE

omenia sinuosa (Roth) Derbes et Solier. Station 1, Subst. 3.

vopteris delicatula Lamouroux. Station 1, Subst. 4.

vopteris Justii Lamouroux. Station 4, washed ashore.

na Vickersiae Hoyt. Station 1, Subst. 1.

assum filipendula C. Agardh. Station 1, Subst. 3.

RHODOPHYCEAE

dium corneum (Hudson) Lamouroux. Station 1, Subst. 3.

ocladia sp. Station 4.

naema ? sp. Station 1, Subst. 1.

rea musciformis (Wolfen) Lamouroux. Station 1, Subst. 1, 2.

simenia uvaria (L.) J. Agardh. Station 3 and Station 4, washed
shore.

uthophora spicifera (Vahl) Børgesen. Station 3, Subst. 1, 2.

encia papillosa (Forskall) Greville. Station 1, Subst. 1.

eloupia cuneifolia J. Agardh. Station 1, Subst. 2, 3.

illina cubensis (Montagne) Kützing. Station 1, Subst. 1.

EMBRIOPHYTA MONOCOTYLEDONEAE

assia testudinum König. Station 1, Subst. 3, 4. Station 4. Station
Subst. 3.

godium filiforme Kützing. Station 3, Subst. 4.

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SPOTTED AND BROWN SHRIMP POSTLARVAE (*PENAEUS*) IN NORTH CAROLINA

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ABSTRACT

Diagnostic characters for the postlarvae of *Penaeus setiferus* and *P. braziliensis* (as understood prior to 1939) are reviewed. Differentiating characters for *P. duorarum* and *P. aztecus* postlarvae are given. The determinations, based on plankton tows, include body size, rostral proportions, relative length of the third pereopod and shape of the antennal scale. The determinations are confirmed by rearing experiments.

INTRODUCTION

Shrimps of the genus *Penaeus* pass through a number of larval and postlarval stages during their development. The larval and early postlarval stages of some species appear to be confined largely to the ocean. Middle to late postlarval stages are found in estuarine nursery areas. At times, postlarvae of more than one species may be found in the same places, and, because the closely related species are similar in appearance, identification is difficult. To overcome this difficulty some attempts at rearing penaeids from the egg have been made; however, rearing young of known parentage for the purpose of determining the developmental stages in different species has been successful in only a few experiments.

Pearson (1939) made one of the first and most thorough of these identification studies along the southeast and gulf coasts of the United States. He was concerned primarily with the white shrimp, *Penaeus setiferus* (Linn.), but also studied developmental stages of other species and made an illuminating comparison between postlarval stages of *P. setiferus* and what was then known as *P. braziliensis* Lalle. (In a footnote, Pearson (1939) stated that this species was probably referable to *P. aztecus* Ives, the brown shrimp, but the exact identity of the species he studied remains undetermined. These postlarvae will be designated as "*braziliensis*" in the remainder of this paper). Heegaard (1953) restudied the spawning and larval development of *P. setiferus* in Texas, and Johnson and Fielding (1956) propagated this species in captivity in Florida, studying the developmental stages in the course of their experimentation.

Because inducement of spawning in captive adults and the rearing

of captive young penaeids has proved difficult, students have been forced to attempt identifications of larvae and postlarvae from the wild. Two factors which may lead to confusion in making such identifications are: (1) the stages of more than one species may mistakenly be combined in a single developmental history, and (2) some variations may be considered as developmental stages of two or more species because the range of variation within each species is not known.

In North Carolina the seasons during which juvenile *P. setiferus*, *P. aztecus*, and *P. duorarum* Burkenroad appear on the nursery grounds are fairly distinct (Williams, 1955a). Juveniles of *aztecus* are first found from mid-April to mid-May with perhaps some recruitment through the summer, those of *duorarum* from late June to October and the young of *setiferus* from late June to mid-August. The only appreciable overlap in the juvenile recruitment periods of these three species is that of *setiferus* and *duorarum* from late June to mid-August. It seems that any postlarvae entering North Carolina sounds prior to mid-April would be *aztecus*. Postlarvae entering the sounds from mid-June to mid-August could be either *setiferus* or *duorarum* and those found after mid-August would likely be *duorarum*. This combination of circumstances in which recruitment periods are fairly distinct, the number of species is small, and the occurrence of more than one species at a time is limited appears to be of great advantage in determining whether or not postlarvae of these three species are morphologically distinct. The remainder of this paper is a discussion of how the identifications of postlarvae have been made in North Carolina.

Special thanks are due to A. Barrett Smith and Warren J. Bell who assisted with the plankton tows and rearing experiments in 1957 and 1958 respectively.

METHODS OF COLLECTING

In December, 1956, weekly plankton tows were begun at the University of North Carolina Institute of Fisheries Research pier on Boggy Sound, Morehead City, Carteret County, North Carolina. The pier is located approximately five miles west of Beaufort Inlet on the Inland Waterway where stages of the tide lag approximately $1\frac{3}{4}$ hour behind those at the inlet. Depth of water at the pier is approximately 18 feet at mean low water. Current velocities are sufficient at maximum flood to cause a net tied to the pier to stream at the surface.

The cone-shaped net used for the tows was five feet in diameter at the mouth by 13 feet in length. The bag was made of knitted nylon.

TABLE 1

NUMBERS OF *Penaeus aztecus* AND *P. duorarum* POSTLARVAE COLLECTED NEAR BEAUFORT INLET, NORTH CAROLINA, IN 1957.

	Jan.		Feb.		Mar.		Apr.		May										
	21	26	2	13	20	1	8	16	1	10	15	23	1	6	14	23	29		
<i>P. aztecus</i>	0	0	4	15	99	529	111	37	20	103	20	0	0	9	3	0	0		
<i>P. duorarum</i>																21	3		
	Jun.		Jul.		Aug.		Oct.		Nov.										
	1	4	12	19	27	2	11	17	26	30	8	16	24	28	9	16	23	31	22
<i>P. aztecus</i>																5	0	2	2
<i>P. duorarum</i>	6	10	4	45	148	53	0	106	91	117	79	77	258	50	8	21	0	5	0

with 1.5 mm mesh. A half-gallon glass jar was used as the catch bucket, but specimens were usually taken from the lower end of the funnel as well as from the jar.

Tows for decapod larvae and postlarvae have been made in this area during both daylight and darkness but in the present study tows were made at night at or near maximum flood. Collections of other forms, especially fishes, were sought at the same time and experience showed that the most complete collections could be made at night. Tows were made at fairly regular intervals until September 1957, then were sporadic until mid-November when the work ceased for the remainder of the year because waste from a menhaden reduction plant nearby made the water too dirty for sampling purposes (Table 1). Unfortunately, no tows were made from January to March 1958, but they were resumed in April, and have been continued to the present. Only 1957 data are included in Table 1.

REARING METHODS

On March 29 and April 2, 1957, a number of postlarvae of identical appearance were taken from Bogue Sound and placed in a 1 by 1½' by 2½' glass-sided aquarium supplied with running sea water filtered through a sand-shell mixture. The shrimp were fed *Artemia* nauplii. The *Artemia* were kept concentrated at one end of the aquarium, opposite the drain, by constant illumination from above with a 150-watt Pyrex flood lamp. Shrimp postlarvae did not actively pursue this prey but would seize and eat *Artemia* which were in their path.

Noticeable growth began when detritus commenced to gather on the aquarium bottom. This material was a combination of dead *Artemia* silt from the salt water lines which overflowed the filter while the pipes were being cleaned; and whatever microorganisms grew in the material. Algal growth on the aquarium sides and ends was not great. The shrimp sorted through the bottom material almost constantly. Later, pieces of ground fish were dropped in the aquarium, and the shrimp ate these bits actively. These findings are similar to those of Hudinaga (1942) and Pearson (1939) who found that captive postlarvae soon settle to the bottom and begin feeding. Both these authors found that shrimp this size will eat algae but that animal supplement is needed in the diet to promote rapid growth.

In June and July, 1957, an unsuccessful attempt was made to rear postlarvae in half-gallon jars filled with standing water. The water was

nged daily. Some of the animals were fed *Artemia* nauplii and some e fed green algae. None of these animals grew well though they did ease somewhat in size. Those fed algae had green guts and left umerous castings in the jars each day. Later the food of all was nged to a shredded commercial chicken feed, but this change reed in an almost immediate mass mortality.

another group of the postlarvae found in summer was reared in ust 1958, by the method described above for the running water arium. Results were comparable to those obtained in spring, 1957, a good survival and a reasonably rapid rate of growth.

POSTLARVAL CHARACTERS OF TAXONOMIC VALUE

earson (1939:30) listed four criteria for separating the early postae of *setiferus* and "*braziliensis*." (1) The rostrum of *setiferus* nds slightly more than halfway along the length of the eye, whereas of "*braziliensis*" extends to or nearly to the distal edge of the eye. The two posterior spines on the rostral ridge are closer together *setiferus* than in "*braziliensis*." (3) These rostral spines are usually ller in *setiferus* than in "*braziliensis*." (4) The third pereopods, n extended, reach to or nearly to the distal edge of the eye in *setiferus*, but they extend past the eye in "*braziliensis*." In addition to e criteria Pearson discussed and figured parts of the body of these is at total body lengths of 5.0, 5.8, 7.4, 8.0, 9.6, 12, 17, 27, and nm.

Two other characters have been found to be useful in identification hese postlarvae. The antennal scales appear to have distinctive es in different species during the postlarval stages, though they are arently alike in the adults; and, a specific difference in body size pparent.

earson (1939) established a basis for size descriptions using the th measurement, tip of rostrum to tip of telson, but because the mp are usually flexed in preservation it is difficult to obtain acy with this measurement. The cephalothorax measurement, tip of rum to rear dorsal edge of the carapace, has been used here. This surement can be made easily under a binocular microscope with aid of an ocular micrometer or an ocular grid while the specimen is g on its side. One possible source of error in applying this measure dgment of the exact point at which the rear dorsal edge of the apace ends. Usually this is apparent, but occasionally some manipu-

lation of the specimen is necessary in order to determine this precisely accurately. The specimen shown in Fig. 4 is approximately 10 mm total length.

POSTLARVAL DETERMINATIONS

When all the samples taken in 1957 are reviewed (Table 1), it is apparent that they can be treated broadly as two series, a February-May and a May-November series. There is a recruitment period in winter and spring which swells to peak intensity about March 1. Recruitment thereafter diminishes to a low point about May 1 followed by a period of relatively low-level recruitment. This gives way to renewed but erratic activity in summer which tapers off to another low level in fall.

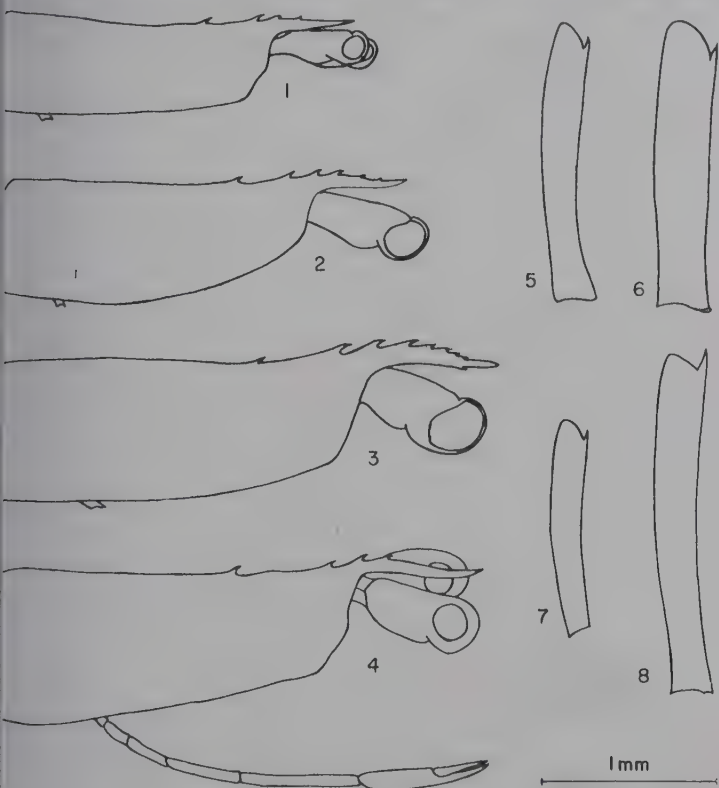
TABLE 2

CEPHALOTHORAX LENGTHS FOR TWO GROUPS OF POSTLARVAL PENAEIDS.

	Feb. 20	Mar. 16	Apr. 10	May 9
Number in Sample	30	30	31	9
Total Specimens	100.	Range of Variation 2.8-3.6 mm x = 3.2 mm		
	June 19	Jul. 26	Aug. 24	Oct. 10
Number in Sample	25	29	26	20
Total Specimens	100.	Range of Variation 1.6-3.2 mm x = 2.43 mm		
"t" = 25.198	Significant at 1% level.			

The feature most apparent in a cursory examination of the samples is the individual size difference between the February-May and the May-November series. The winter-spring recruits are larger than those in the summer-fall series (Table 2). Pearson (1939:37) also noted that the winter specimens of "*braziliensis*" were larger than those taken in spring and summer. There is almost no overlap in the range of cephalothorax length for these two groups. A "t" test (Table 2) shows that the two groups are distinct. Judging age by the number of dorsal spines, the samples were of comparable stages of development, though a few individuals in the summer series were more mature (Fig. 3). A few of these had as many as eight dorsal spines on the rostrum and cephalothorax. At a total body length of about 10 mm (Fig. 4), nearly all of the February-May postlarvae were in a stage comparable to that shown in Pearson's Fig. 24 with four dorsal spines on the rostrum and cephalothorax. Among Pearson's four criteria for separating early postlarvae, the relationship between the tip of the rostrum and the distal edge of the eye is the most apparent. A

gh the form of the rostrum changes with age, this relationship
s for the early postlarval stages until a total body length of about
m is attained (Pearson, 1939:33). In the present samples, all
ividuals taken from February to May had rostral tips which reached
e distal edge of the eye (Fig. 4). In the May-November series
ly all individuals had rostral tips which rarely extended as far as
distal edge of the eye. Individuals in this series with rostral tips
h did reach the distal edge of the eye were either middle to late
arvae with numerous dorsal spines (Fig. 3), or a few large indi-



FIGURES 1-3. Carapace of postlarval *Penaeus duorarum* showing origin of third pereopod. Figure 4. Carapace of postlarval *P. aztecus* showing third pereopod extended. Figures 5-7. Antennal scales of postlarval *P. duorarum*. Figure 8. Antennal scale of *P. aztecus*.

viduals taken in October and November which were similar to the present in the February-May series.

All individuals examined in the 1957 collections had third peropods which extended to or beyond the distal edge of the eye (Fig. 1). In practice this length relationship was difficult to determine. The legs of preserved specimens are usually fixed in a tangle, and attempts to extend the third leg toward the eye usually result in breaking the leg. Because of the joints and flexures in the leg, as well as its brittleness, this character is subject to variation. Aside from the difficulties of measurement, all of these specimens seemed to fit Pearson's fourth criterion for "*braziliensis*" for none of the specimens examined had third legs which did not extend to the distal edge of the eye.

The results of the rearing experiment initiated on March 29 and April 2 confirmed the validity of the characters established by Pearson for the species "*braziliensis*" which he later tentatively referred to as *aztecus*. On May 15 the one survivor in this experiment was fixed and determined as *aztecus* by established juvenile and subadult characters (Williams, 1953). The specimen was 38 mm in total length.

The unproductive rearing experiments of summer, 1957, were of no help in establishing identity of the summer-fall series but the rearing experiment of August, 1958, produced juveniles which were determined as *duorarum* (Williams, 1953). The previous information on recruitment of juveniles, the small size of the postlarvae and the relationship between the rostrum and eye in this series (Fig. 1-3) suggested that *setiferus* and *duorarum* might be mixed in the summer samples. This possibility was strengthened by the fact that some of Pearson's slide mounts that were available for study showed *setiferus* postlarvae to be smaller than *aztecus* postlarvae. Unfortunately, little else could be learned from these deteriorated mounts.

Other characters were sought which would supplement Pearson's fourth criterion. The only character of value found was the shape of the antennal scale. Postlarval *aztecus* in the February-May series had antennal scales nearly uniform in shape with the lateral spine extending beyond the broadly rounded tip (Fig. 8). In contrast all specimens in the summer-fall series had antennal scales in which the tip was more or less acutely rounded with the apex near the mesial aspect of the tip. The lateral spine did not reach the tip. Figures 5-7 show some common variations in the form of this structure which were seen in different growth stages. From the relationships between the third leg and eye and the shape of the antennal scales it was concluded that

mens in the May-November collections were *duorarum* except for *aztecus* found in October and November.

Penaeus setiferus in North Carolina has a notably discontinuous distribution (Williams, 1955b). Though juvenile white shrimp occur in estuaries near Beaufort Inlet, they have not been abundant in recent years. In the present series of samples no postlarvae of this species could be identified positively by any of Pearson's criteria. Postlarvae of this species would be expected to be most abundant in early June. The results of tows during this period were small and the specimens collected were no different in structure than those taken in large collections later in the year. Postlarval *setiferus* may closely resemble *duorarum* but a description of postlarvae of this species from North Carolina awaits further study.

PROVISIONAL KEY TO EARLY POSTLARVAE

LESSER 3.6 MM CEPHALOTHORAX LENGTH OR 12 MM TOTAL LENGTH

Tip of rostrum extending to distal edge of eye; third pereopod extending to or beyond distal edge of eye.

1. Antennal scale broadly rounded distally, lateral spine exceeding tip *Penaeus aztecus*
2. Antennal scale acutely rounded distally with apex near mesio-distal border, lateral spine not reaching tip (middle postlarvae with several rostral spines) *Penaeus duorarum*

Tip of rostrum not extending to distal edge of eye.

1. Third pereopod extending to distal edge of eye; antennal scale acutely rounded distally with apex near mesio-distal border, lateral spine not reaching tip *Penaeus duorarum*
2. Third pereopod not extending beyond distal edge of eye, often not reaching distal edge of eye *Penaeus setiferus*

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PRELIMINARY INVESTIGATION OF THE FECAL PELLETS OF CERTAIN INVERTEBRATES OF THE SOUTH FLORIDA AREA¹

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ABSTRACT

Representative invertebrates from the South Florida area were collected and their fecal pellets were studied. The shape, consistency, presence or absence of external and internal sculpture were observed, and cross-sections of the pellets were made where possible. Pellets of gastropod and pelecypod mollusks were the main objects of study; some crustacean groups were also collected for study.

INTRODUCTION

Moore (1931) has shown that specific differences exist in many gastropod and crustacean fecal pellets, especially where external sculpturing or internal differentiation is present. Abbott (1954) has studied the shape of the pellet as well as the relation of the pellets to the animal in the gut as a character to separate two closely related species of gastropod mollusks. Moore (1939) indicated the importance to the marine geologist of the presence of pellets in sediments. Their presence could possibly yield clues as to the animals inhabiting the area or the water mass above the area. Also these pellets may serve as accumulation centers for phosphates, and they may be the cores of concretions. Since that time various geologists (Parejas, 1935, and Killip, 1954) have found similar relationships. Moore and Kruse (1956) have given an excellent resume of fecal pellets of marine animals.

The animals mentioned in this paper were collected at several locations in Biscayne Bay, the Florida Keys, and at Marco Island on the west coast of Florida. Some collections were made in conjunction with field trips to the outer Florida reefs with the General Marine Biology class of The Marine Laboratory.

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METHODS

As the animals were collected they were placed in separate jars so that the pellets of each animal could be kept separate from those of any other animals collected at the same locality. The specimens were allowed to remain in the jars for a period of not more than twelve hours. At the end of that time, the animals and their pellets were preserved in 5 per cent sea water formalin. The specimens were stored in this medium until they could be studied.

The animals were later identified at the laboratory, and the pellets were measured with an ocular micrometer and drawn with the aid of a camera lucida. All measurements and drawings were done with the aid of a binocular dissecting microscope. At the same time, the length of the pelecypods and the height of the gastropods were measured, so that an idea of the size of the pellet in relation to the size of the animal could be obtained.

Cross-sections of the pellets were made by embedding them in solidified non-nutrient agar-agar medium. A hot needle was used to etch a shallow furrow in the surface of a small block of the agar-agar. The pellet was then laid in this furrow; excess water was removed with a small piece of tissue, and the pellet was then covered with warm, liquid agar. Upon cooling, the embedded pellet was then sectioned. For most pellets, the agar-agar provided enough support so that sectioning was possible.

For the examination of the pellets of some animals it was not feasible to embed the guts in paraffin, as outlined by Moore (1931).

Due to the consistency of the material to be embedded, little success was had with this method. Future work must be done on the preparations of cross-sections of both pellets and guts.

Phylum MOLLUSCA

The specimens collected and examined have been placed in family modified after that used by Abbott, 1954.

Class GASTROPODA

Family TROCHIDAE

Stomatostoma jujubinum Gmelin.

Animal. The specimen, 17 mm in height, shed an undifferentiated rod broken into pieces 1 to 3 mm in length and $\frac{1}{2}$ to $\frac{3}{4}$ mm in width. The rod was homogeneous in consistency, and was circular in cross-section.

Family TURBINIDAE

Astraea americana Gmelin.

Animal. This species of *Astraea* shed a rod quite different in external appearance from *A. longispina*. The specimen, 25 mm high, shed a rod that was broken into pieces up to 3 mm in length and 0.7 mm in width. On one surface of the rod there was a longitudinal ridge. The height of this ridge could not be determined, but was estimated to be approximately of the same dimensions as the width, and ranged from 0.2 to 0.3 mm. The pellet was of even consistency and there was no apparent internal sorting of material.

Astraea longispina Lamarck.

Animal. This animal, 9 mm in height, yielded an apparently undifferentiated rod which had a width of 0.5 to 0.6 mm and was broken into pieces up to 2 mm long. The rod was composed of rather coarse material, and there was no apparent segregation of material within the rod. The structure of this rod is rather surprising in view of the external appearance of the rod in another species of the genus, *A. americana*. It is quite possible that the rod shed by this animal was not firm enough to hold the sculpture.

Stomatostoma castaneus Gmelin. Fig. 3b, 4b.

Animals. The specimens shed broken pieces of rods, each piece about 1 mm long. An animal 15 mm long shed pellets with a diameter of 0.5 mm. Those shed by one of the specimens had a narrow but well-defined canal running longitudinally. The pellet was loosely constructed to allow cross-sectioning, but the canal appeared to be as deep as wide, approximately 0.15 mm. The rods were

yellow-white in color, of a creamy consistency with some darker particles spread throughout their length.

Family NERITIDAE

Nerita fulgurans Gmelin. Fig. 3a.

5 specimens. This species shed an externally undifferentiated which was usually broken into pieces ranging from 1 to 3 mm length. An animal 18 mm high (largest measurement) yielded pellets with a width of 0.71 mm. The rod was round in cross-section, although usually straight, it was slightly curved in some specimens. The texture was fine and homogeneous, and the pellets were of a lo consistency. Occasionally, large granules were observed in the r

Nerita tessellata Gmelin.

4 specimens. An animal 12 mm high (largest measurement) yielded a rod which was broken into smaller pieces. The fragments were f

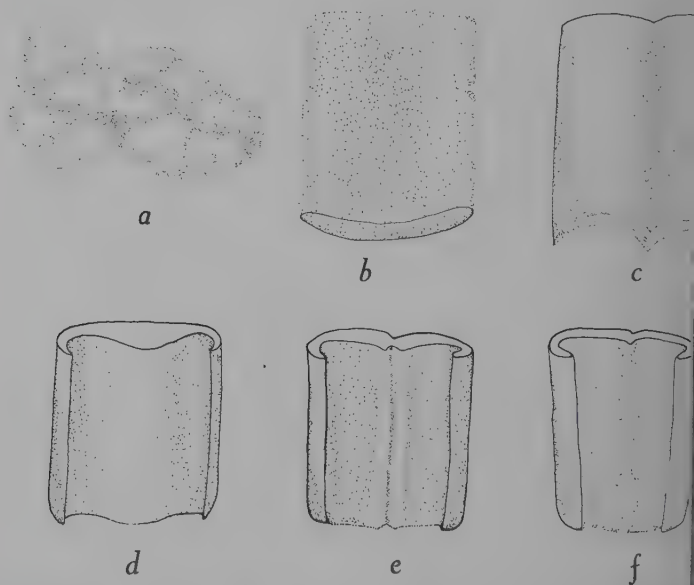


FIGURE 1. a, *Thais rustica*, 15X; b, *Arca umbonata*, 120X; c, *Brachidexustus*, 75X; d, *Plicatula gibbosa*, 90X; e, *Volsella citrinus*, 60X; f, *gnomon radiata*, 60X.

to 2.0 mm long and 0.4 to 0.5 mm wide. In the pellets of this animal the larger, coarser granules were found in the center, while finer, smoother material made up the external layer. The rod was found in cross-section.

Nerita versicolor Gmelin.

specimens. A specimen 19 mm in length yielded plain, undifferentiated rods broken into pieces up to 5 mm in length, with a width of 0.5 mm. One of the rods examined had a layer of very fine material on one surface. This was not thick enough to show up in cross-section. In general, the rods of this animal were of a finer consistency than the preceding species of *Nerita*. There was no evidence of coarser material at the center.

Nerita peloronta Linnaeus.

Although observed in the field, this species was not collected. However, the pellets were observed and were of the same nature as those of the species of *Nerita* already discussed, that is, they were externally differentiated.

Family PLANAXIDAE

Planaxis lineatus DaCosta.

animals. This species shed pellets which were ovoid in shape. An animal 8.5 mm in height yielded pellets which were 0.4 to 0.6 mm in length and 0.12 to 0.15 mm in width. They were smooth and homogeneous, and appeared circular in cross-section.

Family MODULIDAE

Modiolus modiolus Linnaeus.

animals. This species shed pellets that were ovoid to ellipsoid in shape. An animal 8.5 mm in height yielded pellets that were 1.5 mm long and 0.30 to 0.36 mm wide. They were thin, white, very irregular in outline, and homogeneous in consistency.

Family POTAMIDIDAE

Potamilla minima Gmelin. Fig. 2c.

animals. An animal 10 mm high shed ovoid pellets that ranged from 0.61 to 0.66 mm in length and 0.18 to 0.21 mm in width. They were smooth externally and round in cross-section. Internal differentiation was not observed.

In a recent paper, Kornicker and Purdy (1957) found that Bimini, Bahamas, *Batillaria minima* formed a significant portion of marine sediment in the shallow water of the northern extremity of Bimini lagoon.

Family LITTORINIDAE

Littorina angulifera Lamarck.

3 animals. This species shed the typical littorinid pellet as described by Moore (1931). An animal 11 mm in height shed pellets ranging in length from 1.1 to 1.4 mm and in width from 0.3 to 0.5 mm. They were fine in consistency and quite firm. There was a great deal of mucus associated with the pellets.

Abbott (1954a) showed figures of the pellets of *Echininus nodulosus* Pfeiffer and *Nodilittorina* (- *Tectarius*) *tuberculata* Menke. He described the pellets of *Echininus*. He states that "the feces of many, if not all, Littorinidae are relatively short (2 or 3 times as long as wide) and are lined up in the rectum, one directly behind the other. Although Abbott feels that this character is not necessarily of phylogenetic importance, he used the shape and the position of the pellets in the gut, along with other characters, to separate *Echininus* from *Modulus modulus* Linnaeus; *Echininus* had previously been placed in the Family Modulidae.

The authors have observed but not measured the pellets of *Tectarius muricatus* Linnaeus, *Nodilittorina tuberculata* Menke, and *Echininus nodulosus* Pfeiffer and noted that the pellets of all three correspond to those already described from the family Littorinidae.

Family CERITHIIDAE

Cerithium eburneum Bruguière.

1 animal. This specimen, 12 mm in height, shed ovoid pellets which ranged in length from 0.4 to 1.0 mm, with an average length of 0.6 mm. They ranged in width from 0.3 to 0.5 mm. The color of the pellets was light, and they were fine and homogeneous in texture.

Cerithium literatum Born. Fig. 2b.

5 animals. An animal 10 mm high shed ovoid pellets averaging 0.6 mm in length and 0.18 to 0.24 mm in width. The pellets were finely granular, yellow in color with a few darker granules interspersed throughout the pellet. They appeared to be enclosed within a thin gelatinous sheath.

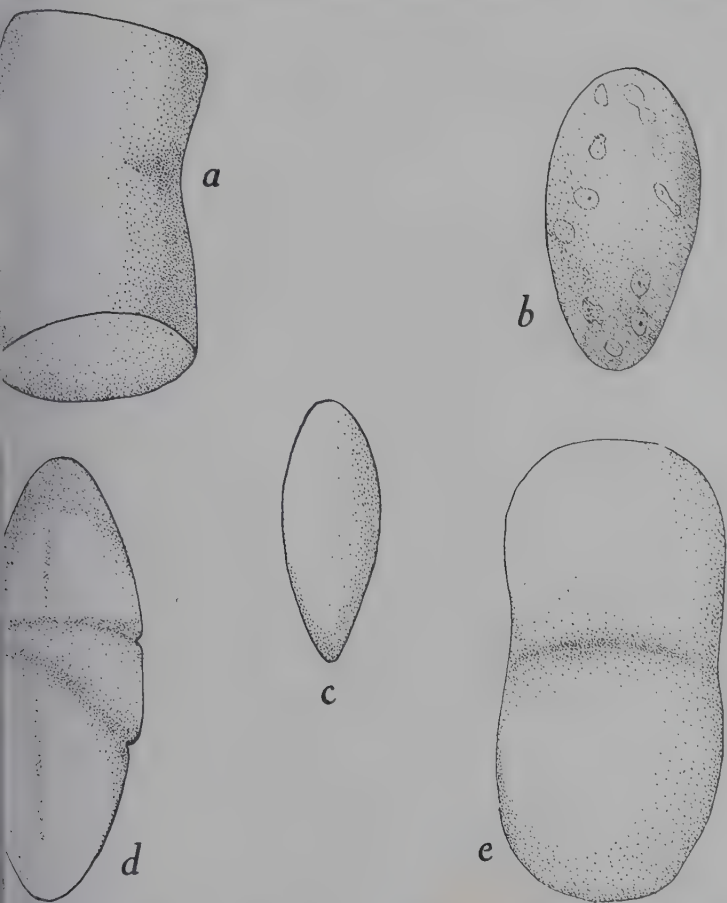


FIGURE 2. a, *Melampus coffeus*, 60X; b, *Cerithium literatum*, 8X; c, *Batillaria* sp., 75X; d, *Acanthopleura granulata*, 8X; e, *Ischnochiton floridana*, 8X.

Family STROMBIDAE

Strombus gigas Linnaeus.

Animals. An animal of 200 mm length shed a rod which was composed of smaller ovoid bodies approximately 2 mm in length. The smaller ovoid bodies were entirely encased in a gelatinous sheath and were in no specific arrangement.

The fecal mass of the species slightly resembles that of *Thais rustica* Lamarck. Both of these species are carnivorous in nature, and both shed a large rod, held together by mucous, which was composed of many smaller ovoid or shapeless particles irregularly disposed.

Family MURICIDAE

Thais rustica Lamarck. Fig. 1a.

1 animal. This animal produced a highly convoluted rod, broken into short pieces. The width ranged from 1.07 to 1.3 mm. Because of the fine consistency, cross-sectioning was not possible. A longitudinal canal was present on the surface of the rod; from this canal branched others that gave the rod its convoluted appearance. The canals gave the rod the appearance of many irregularly shaped masses held together by mucous.

Family MELONGENIDAE

Melongena corona Gmelin.

1 animal. This animal, 39 mm in height, yielded only a broken portion of a rod. The rod was 5 mm in length and 1 mm wide at its widest portion. The rod was black in color, and in it were many small grains which contributed to its irregular outline. It is probable that the outer layer was of a finer consistency than the center. The erosion away of such an outer layer would result in the outline that was observed.

Family TURRIDAE

Crassispira ostrearum Stearns. Fig. 3f.

1 animal. This specimen, 35 mm high, shed ovoid pellets 1.4 to 1.5 mm in length and 0.3 to 0.4 mm in width. They were irregular in outline and had upon their surface numerous grooves intermittently spaced.

Family ONCHIDIIDAE

Onchidella floridana Dall.

1 animal. This specimen, 27.5 mm long, shed an extremely long, highly convoluted pellet. A longitudinal canal of varying width extended the entire length of the rod. Because of the tight, curled nature of its exact length was not determined. It measured 1 mm in length.

Family SIPHONARIIDAE

Ionaria alternata Say.

animals. Their average length was 13 mm. A plain, broken rod shed. The broken pieces were from 2 to 3 mm in length and 0.5 in width. The consistency was homogeneous.

Family ELLOBIIDAE

Ampus coffeus Linnaeus. Fig. 2a.

animals. These animals shed undifferentiated rods broken into pieces of varying lengths. They were circular in cross-section with no internal differentiation discernible. Numerous sand grains and diatom added to their coarseness. The length ranged from 1 to over 3 mm. An animal 10 mm high yielded pieces of rods 2.0 mm in length and 0.56 mm in width.

Class AMPHINEURA

Family ISCHNOCHITONIDAE

Ischnochiton floridanus Pilsbry. Fig. 2e.

animals. From an animal 22 mm long the ovoid pellets averaged 1.5 mm in length and ranged from 0.50 to 0.54 mm in width. They were even in consistency, composed of fine material, and were homogeneous. They were round in cross-section.

Family CHITONIDAE

Anthopleura granulata Gmelin. Fig. 2d.

animals. From an animal 41 mm long the pellets ranged in length from 2.5 to 3.0 mm, in width they ranged from 0.67 to 0.81 mm. The ovoid pellets were round in cross-section. The color was white. They were fine in consistency, with some coarser material concentrated in the center.

Class PELECYPODA

Family ARCIDAE

Umbonata Lamarck. Fig. 1b, 4f.

animal. This specimen, 42.0 mm in length, produced a wide, tightly curved ribbon 0.43 mm in width and 0.05 mm thick. The ribbon was smooth in consistency and broken into pieces varying in length from 0.2 to 0.6 mm.

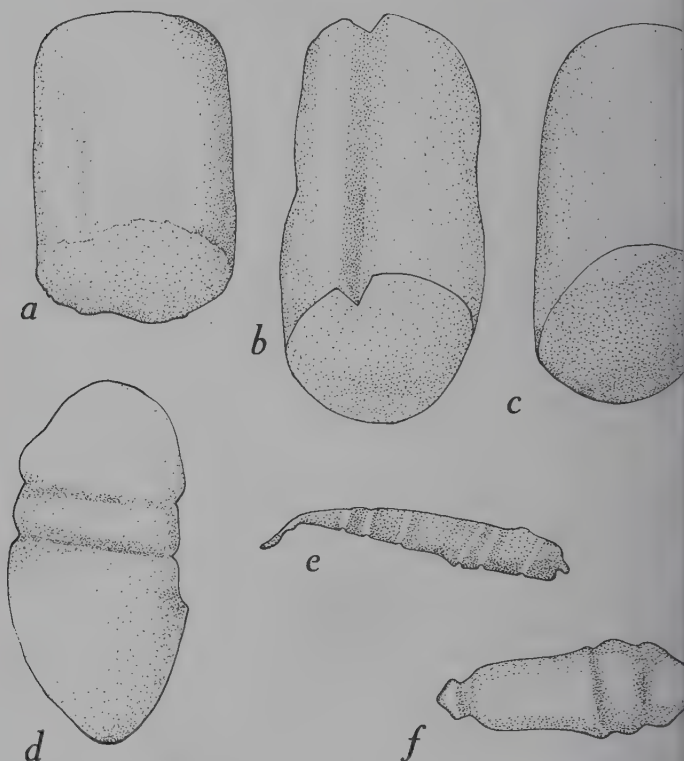


FIGURE 3. a, *Nerita fulgurans*, 38X; b, *Turbo castaneus*, 38X; c, *Clibanella tricolor*, 30X; d, *Chione cancellata*, 75X; e, *Callinectes* sp., 15X; f, *Crassostrea ostrearum* 20X.

Family MYTILIDAE

Brachidontes citrinus Röding (= *Volsella* or *Modiolus citrinus* Fig. 1e, 4c.

1 animal. An individual 31 mm long produced a ribbon-shaped pellet 0.5 mm wide and 0.15 mm thick. The ribbon was broken into pieces under 1 mm in length. It consists of two lateral longitudinal flanges, a median ridge on one surface, and a median, longitudinal

ve on both surfaces. This corresponds quite closely to the descrip-
of the pellets of *Mytilus edulis* as given by Moore (1931), al-
gh these appear to be intermediate between those of *M. edulis*
Modiolus phaseolinus. The main difference is the longitudinal
ve on both surfaces of the ribbon of *Brachidontes citrinus*. How-
this extra longitudinal groove was not observed on all of the
es of the ribbon.

Volsella americana Leach. Fig. 4g.

animal. This animal shed pellets which resemble more closely
e described by Moore (op. cit.) for *M. phaseolinus*. The ribbon
thickened laterally and possesses the median longitudinal thickening
ne surface and the slight groove opposing it on the other surface.
ribbon was broken into pieces 0.32 to 0.43 mm in length and
mm in width. Due to the fine consistency, and the difficulty of
lling, the thickness of the ribbon was not obtained.
oth of these species show close relationship in pellet form to the

Mytilus and *Modiolus* studied by Moore.

Brachidontes exustus Linnaeus. Fig. 1c, 4e.

animals. The largest specimen, 11 mm in length, shed a W-
ed ribbon broken into pieces up to 0.96 mm in length and 0.25
in width. The pellet closely resembles that shed by *Volsella cit-*
r. They differ in that the ends taper to a thin edge and are less
rved, and there is no groove in the center of the upper side.

Family ISOGNOMONIDAE

Isognomon alata Gmelin.

animal. The fecal matter of this specimen was too flocculent to
v drawings to be made. However, some small portions of a ribbon
observed. Those of the closely related *Isognomon radiata* are
ribbed below.

Isognomon radiata Anton. Fig. 1f, 4d.

animals. Because of the shape of the animals, only the largest
surement was taken. An animal with a maximum measurement
7.5 mm shed small fragments of ribbon-shaped pellets 0.39 mm
and 0.55 to 0.59 mm long. The edges of the ribbon were highly
rved. On one surface there was a longitudinal ridge; the other
ce was smooth.

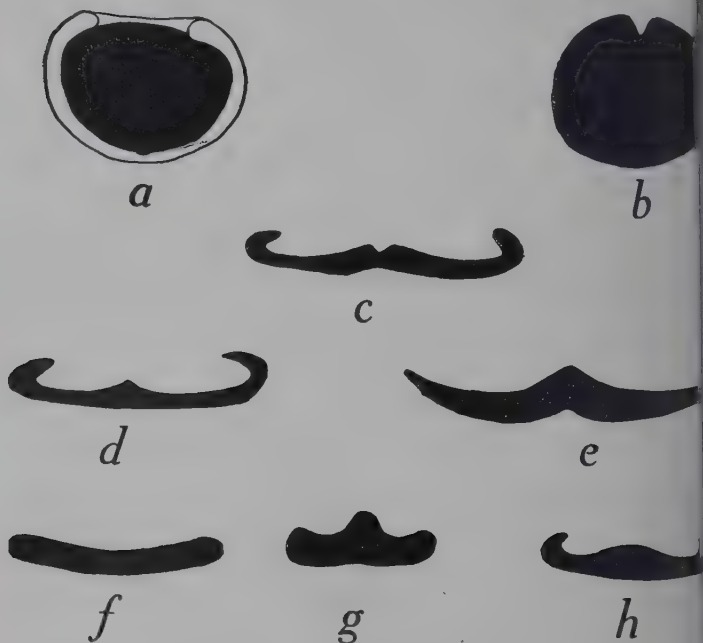


FIGURE 4. Cross-sections. a, *Pseudocyrena floridana*, 1.0 mm wide; b, *Turcastaneus*, 0.5 mm wide; c, *Brachidontes citrinus*, 0.5 mm wide; d, *Isognomon diata*, 0.39 mm wide; e, *Brachidontes exustus*, 0.25 mm wide; f, *Arca umbonata*, 0.43 mm wide; g, *Volsella americana*, 0.46 mm wide; h, *Plicatula gibbosa*, 0.29 mm wide.

Family PLICATULIDAE

Plicatula gibbosa Lamarck. Fig. 1d, 4h.

1 animal. This individual was 0.7 mm long and produced a ribbed shaped pellet that formed a "W" in cross-section. Although the ribbing was in fragments, the longitudinal groove was easily seen. The ribbing was 0.3 mm wide.

Family PECTINIDAE

Pecten ziczac Linnaeus.

1 animal. This specimen, 44 mm long, produced only 2 pellets 0.69 and 1.0 mm long. All of the remainder of the fecal matter was

ulent. The pellets were yellow in color, slightly granular, homogeneous, and irregular in shape. Moore (1931) observed that all species of this family which he examined shed rod-like pellets having angular or trefoil cross-section. The authors feel that those shed by *S. ziczac* and examined by us were either starvation pellets or were dofeces which are given off by all filter-feeding animals.

Family LIMIDAE

S. lima Linnaeus.

animal. This individual, 37 mm long, shed rod-shaped pellets appeared circular in cross-section. The pellets, 0.9 to 1.2 mm and 0.23 wide, were irregular in outline and transversely striated.

Family CORBICULIIDAE

Myrcocyrena floridana Conrad. Fig. 4a.

animals. One specimen, 27.5 mm long, shed a rod broken into 11 pieces up to 1 mm in length. The pellet was slightly compressed at the ends, and had along one surface a shallow canal. The canal was composed of darker and coarser material than was the remaining surface. The rod was 1 mm wide at the widest point. There appeared to be a concentration of coarser material towards the center.

Family CARDIIDAE

Myrcocardium medium Linnaeus.

animal. This specimen, 20 mm long, released pellets with two distinct shapes. The first of these pellets was ovoid in shape, and had a maximum length of 0.55 mm and a width of 0.37 mm. The second of the pellets was much more elongate. It was 1.0 mm long and 0.22 mm wide. Both of the pellets were smooth in consistency, and the smaller ones were slightly smoother than the larger.

Family VENERIDAE

S. cancellata Linnaeus. Fig. 3d.

animal. This specimen, 28 mm long, produced a curved and rod-shaped pellet with a width of 0.1 mm. It was highly granular and creamy-white in color. It is possible that the constrictions seen in the feces are an indication of a starvation pellet; this was definitely determined as no others were shed.

Family DONACIDAE

Donax variabilis Say.

1 animal. This individual, 19 mm long, shed a rod-shaped pellet 1.5 mm in length. The width was not determined as the edges of the pellet were flocculent. It was brown in color.

Phylum ANNELIDA

Family AMPHINOMIDAE

Eurythoe complanata Pallas.

1 animal. This was the only representative of the annelids that was studied. This individual, approximately 40 mm in total length, produced a rod broken into short pieces with a width of 1.0 mm. A longitudinal groove was located on both the dorsal and ventral surfaces. The heavier, more granular material appeared to be concentrated in the grooves. The twin grooves gave the rod a pinched appearance.

Phylum ARTHROPODA

Class CRUSTACEA

Subclass CIRRIPIEDIA

Family BALANIDAE

Balanus amphitrite niveus Darwin.

2 animals. Along the rostro-carinal canal they measured 10 to 15 mm. Broken, irregular rods 0.2 mm and 0.4 mm were given off. The rods were covered by a gelatinous sheath. There was no apparent external sculpture.

Order DECAPODA

Family PAGURIDAE

Clibanarius tricolor (Gibbes). Fig. 3c.

6 animals. This species shed a rod which was broken into pieces 3 mm in length or less. An area of finer, lighter colored material was concentrated on one surface of the rod. This area of finer material appeared as a longitudinal band running the length of the rod. The width varied from 0.8 to 0.9 mm. There were no noticeable longitudinal canals in the rod. The rods tend to be slightly curved rather than straight.

The structure of the pellet of this pagurid differs from the structure of the pellets studied by Moore (1932) in the presence here of the longitudinal area containing the finer material. The significance of this difference may be learned by further study.

Family PORTUNIDAE

inectes sp. Fig. 3e.

animal (immature). This specimen, with a carapace width of 1 mm, produced a ribbon-shaped pellet 3.2 mm long. The ribbon differentiated into light and dark bands, with the coarser material concentrated at one end. Numerous lateral wrinkles were present near the other end. The width of the rod was highly irregular.

SUMMARY

The fecal pellets deposited by certain south Florida invertebrates have been described, and external features and selected pellet cross-sections have been illustrated. Where appropriate, comparisons have been made with European counterparts.

Species whose pellets have been examined have been added to the list of known pellet producers compiled by Moore and Kruse (1966). South Florida species have been so designated in the list.

64 per cent of the species investigated shed ovoid, ellipsoid to rod-like, or rod-like pellets that cannot be used for specific identification. Of the remaining 36 per cent, 17 per cent shed ribbon-like pellets and 19 per cent shed rods with external longitudinal sculpture. The characteristics of the last two groups of pellets may allow the producer to be identified to group, but specific identification can be made in only a few instances where internal differentiation is present.

Although large series of animals of each species were not examined, the pellet type of each group studied by the present writers was in close agreement with those previously described by Moore. The majority of the animals in a given group, usually at the generic level, produced similar pellets.

TABLE 1

KNOWN PRODUCERS OF FECAL PELLETS AND CLASSIFICATION OF THESE PELLETS ACCORDING TO SHAPE. ASTERISK DENOTES AN ANIMAL FROM SOUTH FLORIDA (AFTER MOORE AND KRUSE, 1956, WITH ADDITIONS BY MANNING AND KUMPF).

<i>Pellet shape</i>	<i>Species</i>	<i>Family</i>
Ovoid or ellipsoid	<i>Littorina littorea</i>	Littorinidae
	<i>L. littoralis</i>	"
	<i>L. neritoides</i>	"
	<i>L. rudis</i>	"
	* <i>L. angulifera</i>	"
	* <i>L. ziczac</i>	"
	* <i>Echininus nodulosus</i>	"
	* <i>Nodilittorina tuberculata</i>	"
	* <i>Tectarius muricatus</i>	"
	* <i>Planaxis lineatus</i>	Planaxidae
	* <i>Batillaria minima</i>	Potamididae
	* <i>Cerithium literatum</i>	Cerithiidae
	* <i>Ischnochiton floridanum</i>	Ischnochitonidae
	* <i>Acanthopleura granulata</i>	Chitonidae
	? * <i>Trigoniocardium medium</i>	Cardiidae
	<i>Tellina crassa</i>	Tellinidae
	<i>T. donacina</i>	"
Ellipsoid to rod-like	* <i>Modulus modolus</i>	Modulidae
	* <i>Pecten ziczac</i>	Pectinidae
	* <i>Lima lima</i>	Limidae
	<i>Syndosmya alba</i>	Semelidae
	<i>S. nitida</i>	"
	<i>Tectura virginea</i>	Tecturaidae
Rod-like	<i>Patella vulgata</i>	Patellidae
	* <i>Calliostoma jujubinum</i>	Trochidae
	* <i>Astraea longispina</i>	Turbinidae
	* <i>Nerita fulgurans</i>	Neritidae
	* <i>N. peloronta</i>	"
	* <i>N. tessellata</i>	"
	* <i>N. versicolor</i>	"
	* <i>Melongena corona</i>	Melongenidae
	* <i>Siphonaria alternata</i>	Siphonariidae
	* <i>Melampus coffeus</i>	Ellobiidae
	* <i>Chione cancellata</i>	Veneridae
	* <i>Donax variabilis</i>	Donacidae
	<i>Munida bamffica</i>	Galatheidae
	<i>Parapagurus pilosimanus</i>	Paguridea
	<i>Eupagurus</i> sp.	"
Rod with external longitudinal sculpture	* <i>Callinectes</i> sp.	Portunidae
	* <i>Astraea americana</i>	Turbinidae
	* <i>Turbo castaneus</i>	"
	* <i>Strombus gigas</i>	Strombidae
	* <i>Thais rustica</i>	Muricidae
	* <i>Onchidella floridana</i>	Onchidiidae
	<i>Nucula tenuis</i>	Nuculidae

TABLE 1—Continued

Shape	Species	Family
	<i>N. moorei</i>	Nuculidae
	<i>N. nitida</i>	"
	<i>N. nitida</i> radiate form	"
	<i>N. nucleus</i>	"
	<i>N. radiata</i>	"
	<i>N. sulcata</i>	"
	<i>Chlamys opercularis</i>	Pectinidae
	<i>C. tigrina</i>	"
	<i>C. triradiata</i>	"
	* <i>Pseudocyrena floridana</i>	Corbiculiidae
	* <i>Eurythoe complanata</i>	Amphinomidae
	* <i>Clibanarius tricolor</i>	Paguridae
with external longitudinal sculpture and internal sculpture	<i>Aeglea laevis</i>	Galatheididae
	<i>Galacantha rostrata</i>	"
	<i>Galathea dispersa</i>	"
	<i>G. intermedia</i>	"
	<i>G. squamosa</i>	"
	<i>G. strigosa</i>	"
	<i>Porcellana longicornis</i>	Porcellanidae
	<i>P. platycheles</i>	"
	<i>Hippa asiatica</i>	Hippidae
	<i>Thalassinia anomala</i>	Thalassinidae
	<i>Upogebia stellata</i>	Callianassidae
	<i>U. deltaura</i>	"
with spiral sculpture	<i>Patina pellucida</i>	Patellidae
	<i>Tectura tessulata</i>	Tecturaeidae
with transverse and longitudinal sculpture	<i>Cantharus clelandi</i>	Trochidae
	<i>Gibbula magus</i>	"
	<i>G. cineraria</i>	"
	<i>G. umbilicalis</i>	"
	<i>G. tumida</i>	"
	<i>Chlamys varia</i>	Pectinidae
with plain anterior but internal sculpture on-like	<i>Axius stirhyncus</i>	Axiidae
	<i>Callianassa californiensis</i>	Callianassidae
	<i>C. subterranea</i>	"
	<i>Calocaris macandreae</i>	Axiidae
	* <i>Arca umbonata</i>	Arcidae
	* <i>Brachidontes exustus</i>	Mytilidae
	<i>Modiolus modiolus</i>	"
	<i>M. phaseolinus</i>	"
	<i>Musculus marmoratus</i>	"
	<i>Mytilus edulis</i>	"
	* <i>Volsella americana</i>	"
	* <i>Brachidontes citrinus</i>	"
	* <i>Isognomon alata</i>	Isognomonidae
	* <i>I. radiata</i>	"
	* <i>Plicatula gibbosa</i>	Plicatulidae

TABLE 2

ANIMALS THAT SHED PELLETS OF UNDISCERNIBLE SHAPE.
THE FECAL MASS WAS EITHER DISENTEGRATED OR
FLOCCULENT UPON EXAMINATION.

<i>Class</i>	<i>Family</i>	<i>Species</i>
Gastropoda	Turbinidae	<i>Astraea brevispina</i>
	Calyptraeidae	<i>Crepidula fornicata</i>
	Muricidae	<i>Murex pomum</i>
	"	<i>Drupa nodulosa</i>
	Columbellidae	<i>Nitidella ocellata</i>
	Buccinidae	<i>Cantharus tinctus</i>
	Nassariidae	<i>Nassa vibex</i>
	Fascioliariidae	<i>Fasciolaria distans</i>
	"	<i>F. tulipa</i>
	"	<i>Leucozonia nassa</i>
	Olividae	<i>Olivella nivea</i>
	Marginellidae	<i>Prunum apicinum</i>
	Conidae	<i>Conus jaspideus</i>
	Arcidae	<i>Barbatia candida</i>
Pelecypoda	Glycymeridae	<i>Glycymeris pennaceus</i>
	Mytilidae	<i>Lithophaga nigra</i>
	Isognomonidae	<i>Isognomon semiaurita</i>
	Limidae	<i>Lima lima</i>
	"	<i>L. pellucida</i>
	Pectinidae	<i>Aequipecten gibbus nucleus</i>
	Lucinidae	<i>Lucina pennsylvanica</i>
	"	<i>Codakia orbicularis</i>
	Cardiidae	<i>Trachycardium muricatum</i>

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COLORIMETRIC DETERMINATIONS OF NITRITE AND NITRATE NITROGEN IN BRACKISH COASTAL WATERS¹

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ABSTRACT

A simple, rapid colorimetric procedure has been developed for determining the nitrite content of brackish coastal waters. A slight modification permits analysis of nitrate content. Both methods eliminate conflict with other ions. Each takes but 15 to 20 minutes. They can be used by persons who are not skilled chemists.

The procedures are presented as an aid to geologists and biologists who have had difficulty in correlating rapidly changing lateral, vertical and hourly chemical content with other brackish water data, especially near shore. The nitrite content of Mississippi's coastal water is 0.03 to 0.05 ppm. Nitrate content is 0.04 to 0.06 ppm.

The procedures are modifications of a 1954 method developed by Nelson, Kurtz and Bray for plant and soil analysis. Old colorimetric procedures are utilized in diazotization of sulfanilic acid by the nitrite ion and subsequent coupling with 1-naphthylamine to form a red dye. As in the Nelson-Kurtz-Bray method, reagents are added as powdered mixture which are stable for at least two months. One mixture is used for nitrite only. The other is identical except that powdered zinc is added, to reduce nitrates to nitrites. Nitrate content is the difference between the nitrite determination and the determination after the nitrate is reduced to nitrite.

INTRODUCTION

Geologists and biologists at Gulf Coast Research Laboratory have had difficulty correlating their findings with water behavior. The coastal waters of Mississippi vary laterally, vertically and hourly. Tidal currents, longshore currents and land runoff change the concentrations of both cations and anions. Two anions which are most variable close to shore are nitrite and nitrate. It is probable that similar variations are prevalent on other low, sheltered coasts. It is probable also, that other workers have had difficulty in measuring these changes for lack of rapid procedures.

The colorimetric procedure described here for determining nitrate and nitrites is a modification of a 1954 method by Nelson, Kurtz and

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(1954) for discovering the amounts of these ions in plants and They based their procedure on older methods of the estimation of nitrous oxide.

those procedures and in these procedures being described here, the intensity of a red dye is measured colorimetrically. The dye is made by the azotization of sulfanilic acid by the nitrite ion and subsequent coupling with 1-naphthylamine. These reagents, and manganous sulfate and citric acid added for complexing iron and aluminum, are all combined in a single powder for convenience and preservation. The reagent is added to the brackish water sample after it has been made slightly acidic with acetic acid. The amount of nitrite is determined by comparison with colored standards of known strength. Another powder reagent, identical except for added powdered zinc, brings about the reduction of nitrate to nitrite, and forms the same red dye. Again, by comparison of the intensity of the dye with the standards, the amount of original nitrite and the amount of nitrate as reduced to nitrite is determined. The amount of nitrogen as nitrate can thus be obtained by difference.

These methods have eliminated two difficulties encountered in earlier attempts at determining nitrite content of brackish waters. First, all reactions take place in an acid medium so that aluminum, magnesium, and iron hydroxides do not appear as gels, which, in alkaline solution, cause a turbidity so great that colorimetric comparisons are impossible. Second, the use of powders kept in black-painted bottles and found to be stable for at least two months enable rapid analyses with a minimum of preparation. The most time consuming procedure is preparing the colorimetric standards which, in order to insure against oxidation, should be made twice a day.

Either of two colorimetric methods can be utilized: comparison of optical density through a Nesslerimeter which can be made on shipboard analysis of fresh samples to insure against oxidation of nitrites to nitates; or spectrophotometry in the laboratory when the time factor is so important. The procedure here used is for a Nesslerimeter.

The following pages include directions for making reagents and step-by-step explanations of the procedures. The amounts of reagents used for nitrite content of 0.10 to 0.20 ppm (parts per million) and for nitrate content in the same range. Coastal waters off large rivers would probably require double or triple the amounts of reagents.

Comments are made on the chemistry involved wherever necessary.

The directions here used may seem superfluous to an analytical chemist but the objective is to make the method so clear that investigators but one semester of analytical chemistry can follow them.

REAGENTS FOR NITRITE-NITRATE DETERMINATIONS

1. Standard Nitrate Solution

(A nitrate solution must be used rather than nitrite because nitrite solutions would oxidize to nitrates).

Weigh out 0.607 g NaNO_3 on a tared watchglass.

Dissolve in 500 ml water. Make up to 1 liter.

This solution contains 100 parts per million (ppm) N.

2. Acetic acid (glacial).

3. Powder mixture No. 1 (stable for several months)

Place in a mortar the following: 100 g BaSO_4 (dried at 110 degrees C for one hour), 10 g $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, 2 g finely powdered zinc, powdered citric acid, 4 g sulfanilic acid, 2 g of 1-naphthylamine. Grind in the mortar. Store in bottle painted black on outside. Label "For Nitrate Analysis—Powder #1 with zinc."

4. Powder mixture No. 2 (stable for several months)

Place in a mortar 100 g BaSO_4 (dried at 110 degrees C for one hour), 75 g powdered citric acid, 4 g sulfanilic acid, 10 g $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, and 2 g of 1-naphthylamine. Store in a bottle painted black outside. Label "For Nitrite Analysis—Powder #2."

PREPARATION OF STANDARDS

(TWICE DAILY)

Prepare standards of varying strength nitrate solution for color comparison (after each standard has been reduced to a nitrite). A little practice will enable the operator to recognize the range of concentrations in the brackish waters being analyzed for nitrogen. (The probable range will be 0.01 to 0.10 parts per million.) At first 6 or 8 strengths of standard nitrate solution should be made until the range is determined. But for brevity, the making of only 4 are described.

Use four 100 ml glass-stoppered volumetric flasks.

1. Into No. 1 flask pipette 0.5 ml standard nitrate solution (0.5 mg per ml)
2. Into No. 2 flask pipette 0.1 ml standard nitrate solution (0.1 mg per ml)

Into No. 3 flask pipette 0.15 ml standard nitrate solution (0.01 mg per ml)

Into No. 4 flask pipette 0.2 ml standard nitrate solution (0.01 mg per ml)

Fill each flask to mark with distilled water.

Shake well. Pour contents of each into a glass-stoppered 250 ml Erlenmyer flask.

Add to each Erlenmyer flask exactly 10 ml glacial acetic acid to produce a pH of about 2.

Add to each flask a scoop of No. 1 powder mixture (about 1.0 g). The contained zinc reduces the nitrate to nitrite.

Stopper flasks. Shake each flask vigorously for one minute.

Let stand 10 minutes to develop pink to red color in each.

Pour contents of each stopped flask into separate 100 ml centrifuge cups.

Centrifuge for 3 minutes.

Decant liquid from each cup into separate 50 ml glass-stoppered Nessler tubes.

Place the 4 Nessler tubes with their pink to red contents in the Nesslerimeter.

DETERMINATION OF NITRITES

Pipette 10 ml brackish water into a glass-stoppered 250 ml Erlenmyer flask.

Add 10 ml glacial acetic acid.

Add a scoop (about 1.0 g) No. 2 powder mixture. (This is the mixture which contains no zinc.)

Repeat procedures 9 through 13 under Preparation of Standards.

Compare the intensity of the pink to red dye in the brackish water sample against the pink to red standards set up in the Nesslerimeter.

Calculate amount nitrogen as nitrite nitrogen, as follows: ppm nitrite N = value of standard x 10

DETERMINATION OF COMBINED NITRITES AND NITRATES

Repeat procedures 1 and 2, above.

2. Add a scoop of powder mixture No. 1 (contains zinc). The reduces all nitrate to nitrite as in step No. 8 in Preparation Standards.
3. Compare color intensity as in No. 5 above.
4. Calculate amount of nitrogen as nitrite nitrogen as in No. 5 above. If nitrate nitrogen is present in the brackish water will show up as more nitrogen here than in No. 6, above. the same formula:
$$\text{ppm combined nitrite N \& nitrate N} = \text{value of standard} \times \frac{\text{ppm nitrite N}}{10}$$

DETERMINATION OF NITRATES

$$\text{ppm nitrate N} = \frac{\text{ppm combined nitrite N \& nitrate N} - \text{ppm nitrite N}}{1}$$

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THE GREEN TURTLE (*CHELONIA MYDAS* *MYDAS*) IN FLORIDA¹

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ABSTRACT

This paper records the first definite observations of nesting emergences of the Atlantic green turtle on the coast of North America. Two females were found laying their eggs on the East Coast of Florida, as follows: (1) 10 miles north of Vero Beach, Indian River County, July 11, 1957, T. C. Witham, observer; and (2) about a mile north of the House of Refuge, Hutchinson Island, Martin County, June 27, 1958, R. C. Byrd, observer. Eggs from the latter nest were hatched by Mr. Ross Witham, and the hatchlings are in the collections of the University of Florida. The possibility of using such Florida-oriented hatchlings (should more intensive checking show them to be available in worthwhile numbers) in any future stocking project is discussed.

During the course of separate bibliographic studies of the primitive habits of sea turtles in Florida (Ingle and Smith, 1949, Carr, 1952, 1953) the writers were struck by the scarcity of information on the distribution of green turtle populations in the state prior to the settling of the lower East Coast. Since the days when the earliest accounts of Florida resources and natural history were written the green turtle has been cited as a typically Floridian production. So consistently has Florida been named as a center of green turtle abundance that it was as a surprise to find in print no definite record of a green turtle nesting on a Florida beach, or for that matter anywhere on the mainland of the United States.

The closest approach to such a record is to be found in Audubon's "The Turtlers" (1926), in which he says (p. 199) "On certain parts of the shore (of Florida) hundreds of turtles (by clear implication including green turtles) are known to deposit their eggs," and (p. 207) "I have several times observed them in the act (of laying)." He has also said that the depleted green turtle populations of the Bahamas today no longer breed there but came from Cuba and the mainland. Audubon (1842) implied that besides their breeding activity on Tortugas, green turtles nested on Florida beaches. Although

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William Tecumseh Sherman (1889) said nothing of turtle nest. I was strongly impressed by the importance of the green turtle in the economy of the Florida East Coast. Of green turtles at Fort Pierce where he was stationed in 1840, he said: "They were so cheap and common that the soldiers regarded it as an imposition when compelled to eat green turtle steaks instead of poor Florida beef or the usual mess-pork. I do not recall in my whole experience a spot on earth where fish, oysters and green turtles so abound as at Fort Pierce, Florida" (p. 19). By 1896 we find Brice saying, "The fishermen comment upon the fact that for the past few years the green turtle has been depositing its eggs on Key West and adjacent keys." Inquiries today produce much the same comment. It is curious that the recording of a definite nesting emergence had to await the present paper, written at a time when *Chelonia* has been practically extirpated as a breeding entity in the fauna of the United States.

Some time ago, in looking about for the nesting ground of the ridley turtle (*Lepidochelys kempi*), Carr circulated a questionnaire among people familiar with the loggerhead colonies, asking about arrivals of species other than the loggerhead. This revealed that it was common knowledge that green turtles still come ashore on the beaches between Palm Beach and Melbourne; but it was admitted by all that such occurrences were rare and that the chances of anyone seeing a green turtle on a night's tour of loggerhead rookeries were slim. The somewhat extensive beach-walking experience that Carr accumulated at that time bore this out.

Three years ago, Ingle asked Florida Conservation Agents to watch for green turtles on the beach. In two successive years this campaign yielded a record of nesting, each substantiated by clear photographs that we both have seen, and one supported by examination of hatchlings from the eggs laid. The records are as follows:

1. Two miles north of Vero Beach, Indian River County, Florida; July 11, 1957, 10:30 P.M.: T. C. Cheatham, Agent, observer. Three eggs were collected. Black and white photographs were taken and are in our files.

2. About a mile north of the House of Refuge Museum, Hutchinson Island, Martin County, Florida; June 27, 1958; R. C. Byrd, Agent, observer. Kodachrome pictures were made. This turtle laid 130 eggs which were removed and reburied on the premises of the House of Refuge Museum where they were watched through hatching by M.

Witham. Eighty eggs hatched August 24, 1958, and on that date Witham telephoned Carr, who went down to Stuart and brought hatchlings to the University of Florida for study. A sample from the batch shows the following measurements (in millimeters): greatest straightline length of shell, maximum - 58, minimum - 50, average - 54; greatest straightline width of shell, maximum - 47, minimum - 42, average - 42.

The minimum measurements shown above were from an individual that was conspicuously less advanced than the others and had a yolk-sac of half-inch diameter protruding from its plastron. All had yolk-sacs and egg teeth and none had fed prior to being measured. Although none had as much yolk as the runt, the considerable variation in degree of absorption of yolk probably indicates that the young had been hatching for several days prior to eruption of the nest.

That green turtles were once extremely abundant in Florida is not doubted, but it is difficult to determine, from the accounts of the past, whether the populations here were largely transient, non-breeders as in the case of the green turtle in the Cedar Key-Crystal River area are today (Carr and Caldwell, 1956), or whether Florida really was a major center of reproduction as most early writers said or implied. Some generalized statements were no doubt merely repetitions of earlier sayings. Other writers apparently assumed that breeding occurred in Florida because the grazing flats on the Gulf Coast and in Indian River were so heavily populated with turtles. This does not necessarily follow. It is possible that nesting loggerheads, and the feeding aggregations of green turtles in adjacent waters may have been incorrectly attributed to be aspects of one phenomenon.

It seems more likely, however, that primitive Florida actually was a gathering ground for great nesting assemblages of green turtles. These were quickly blotted out when the Seminole and the white man came, just as they were in Tortugas, in the Cayman Islands, and in Bermuda, and as they will be all through the American tropics unless protection for the few remaining rookeries is provided.

An unexpected aspect of the reproductive pattern apparently shared by sea turtles, which current studies have revealed, is a capacity to exist either in aggregations or as isolated individuals. The full implications of this dual pattern is not clear. It is not known, for example, whether it is a question of resident-versus-migratory breeding, as in the case of some birds, or whether the solitary nesters are simply the die-

hard remnants of once populous nesting colonies wiped out by man.

In any case, these lone females would seem to be in a reproductively hazardous position. Mating occurs at nesting time and the chances of a detached female meeting a male might seem slight, although, to be sure about that, we must wait till we learn whether the sexes go separately to the breeding areas or make the trip together. On the other hand, the eggs laid at a given visit to the beach are not the ones fertilized at that time. They were probably fertilized three years before (Harrisson, 1956, 1956a, Hendrickson, 1958, Carr and Ogren, 1958) and their viability thus depends not on the female's luck that time, but on whether she failed to meet a male on the previous occasion also. With respect to this whole question, we can only say that several complements of isolated nesters that we have watched through incubation have proved to be fertile.

Thus, the occasional arrival, for whatever reason, of a gravid green turtle at a Florida beach suggests the practicability of a management program to restore the lost colonies of this most valuable of all reptiles. The ease with which young green turtles may be brought up to shell lengths of six and eight inches makes it feasible to protect the highly vulnerable, post-hatching stages and bypass the heavy predation that eggs and newly emerged sea turtles must hurdle. Although we know nothing of the ecology of young sea turtles after they have passed the surfline, there can be no doubt that the releasing of a thousand half-pound turtles would be an operation more likely to increase the population than the natural emergence of a thousand hatchlings.

To produce six-inch green turtles in a year you need only unpolluted, unchangingly warm, salt water and a steady supply of chopped fish and marine invertebrates. Possibly, once enough people who recognize green turtles start systematically searching Florida beaches, nesting will prove to be frequent enough to furnish all the eggs needed for a pilot nursery. It would seem sensible to use Florida eggs insofar as possible, simply because they might conceivably hatch out turtles with a genetic inclination to return to Florida when they reach breeding age. On the other hand, if the Florida yield proves insufficient, either eggs or new hatchlings could easily be brought from Caribbean nesting grounds.

The propitious qualities of the green turtle as a subject for conservation and management have been discussed elsewhere (Carr, 1956). To the virtues of the mature animal there can now be added the value

ected toughness of the newly hatched young, which Carr and Ogren found can be carried about, without food or water, in light boxes or even bags, provided only a moist interior is furnished. The discovery that they do not require water in shipping containers enhances the practicability of management practices. They thrive in crowded quarters and show strong resistance to fungus attack and other ailments. At Tortuguero, Carr and Ogren (ms.) kept six more than a year in a narrow four-foot wooden trough; and at the Fort Francois d'Afrique Noire in Dakar Carr was shown healthy one-year old specimens in *fresh* water, in a garden pond.

From every aspect, then, and at all stages of development, the green turtle appears to be a fit subject for management. It can be only a matter of time until somewhere this opportunity is exploited. Although immediately pressing problems preempt present conservation efforts in Florida it may be possible to undertake such a project in the future. The growing interest in the subject indicates that considerable popular support could be expected.

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DISTRIBUTION OF THE BLUE MARLIN AND BLACK MARLIN IN THE INDO-PACIFIC

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ABSTRACT

The distributions of blue marlin (*Makaira mazara*) and black marlin (*Istiompax indicus*) (fishes, family Istiophoridae) are described, with detailed records of occurrences. The popular name, "Indo-Pacific blue marlin" is suggested for *M. mazara*.

In the course of the last ten years, we have been fortunate in being able to examine fresh specimens of marlins from most of the known areas of abundance of these fishes. Having recently returned from an expedition that took us completely around the world on this quest, it seems appropriate to publish a short note on the distribution of two species.

Istiompax indicus (Cuvier)

Black marlin, Shirokajiki

This species is well-known to anglers, who have taken it in the waters of New Zealand and Australia, off the west coast of South and Central America, and off the east coast of Africa. It is a common species in the oriental long-line fisheries of the central Pacific and along the coast of the Orient. We have examined 81 specimens and photographs from the following localities. New Zealand (Bay of Islands)—4; Peru—6; Ecuador—1; Central Pacific (no precise locality)—9; 3°N, 171°W—1; 8°N, 169°E—1; 10°N, 140°E—16; 132°E—10; East coast of Celebes Island—2; Banda Sea—8; Off Taiwan—1; East coast of Taiwan—1; West coast of Taiwan—1; Off Trincomalee, Ceylon—1; East coast of Fadiffolu Atoll, Maldives—1; Male Atoll, Maldives—1 (photograph); 4°N, 67° to 71°E—1; Seychelles Islands—1 (dried head and dorsal fins); Muscat, Arabia—2 (1 stuffed specimen, 1 skeleton, in the British Museum Natural History); West coast of Pemba Island—1; Mozambique—1 (partial skeleton in British Museum Natural History); Mozambique—8; Mauritius—3, plus 4 photographs. It is apparent that *I. indicus* ranges through most of the temperate and tropical parts of the Indian and Pacific Oceans.

The color of this species is quite variable, ranging, in dead specimens, from dark blue-black to nearly white. According to Nichols and Monte (1935), the pale color appears to be one of the chief diagnostic

nostic characteristics of the silver marlin, their subspecies *tahitiensis*. However, LaMonte (1955) has expressed doubts as to the validity of this character and has suggested that it might be the result of glandular imbalance in individual cases. In the commercial markets of Misaki, Japan, and Kaohsiung, Taiwan, there were specimens of *I. indicus* of all sizes (60 to 1133 pounds dressed weight) and of all shades, from the "typical" dark blue-black to a pale dirty white. Japanese fishermen stated that this was a matter of individual variation, and that they considered all these fish to be the same species regardless of color. In Suo, Taiwan, two of the oldest fishermen gave accounts in more detail. In three languages, through two interpreters, the following information was obtained:

"The fish are darker in the water, but become pale in a few hours and remain pale. They are slightly reddish in the water. If they are iced before rigor, they keep the reddish color. But if the fish is iced later, it becomes white."

"Marlin further offshore are darker. Nearer shore, especially in estuaries, they are more greyish. After they are harpooned, the color becomes almost black. We club them to kill them, and then they immediately become the color of eggplant, which fades in about ten minutes."

Personal observation of specimens of *I. indicus* taken on hook and line has shown that their color in the water ranges from pale blue with the appearance of a milky over-wash, to deep blue, almost black. Sometimes bright blue stripes are visible on the sides while the fish are in the water, but these have not been seen to persist after the fish have been brought into the boat. A specimen taken off Trincomalee, Ceylon, appeared dark blue in the water, but changed to a beautiful deep bronze as it was drawn into the boat. The bronze color persisted for perhaps ten minutes. As the bronze disappeared, the sides turned whitish, the dorsum dark blue-black. Another individual, taken along the east side of Fadiffolu Atoll in the Maldives, showed similar color changes, but faded in a matter of about eight hours to an almost uniform pale grey. On the basis of color, then, there seems to be no justification for retaining the subspecies *tahitiensis*.

Makaira mazara (Jordan and Snyder)
Indo-Pacific blue marlin, Kurokajiki

Eighty-two individuals and four photographs of this species have been studied, from the following locations: Australia—1 (photo

1); New Zealand (Bay of Islands)—2 (photographs); Máncora, —1; Hawaii—1 (photograph); Central Pacific (no precise location)—14; 3°S, 125°W—7; 10°N, 170°W—11; 3°N, 171°—9; 8°N, E—15; 8°N, 169°E—14; Off Arugam Bay, Ceylon—1; 4° to 67° to 71°E—8; Bazaruto, Moçambique—1; Mauritius—1. This species appears to occupy much the same range as does *I. indicus*, though long known to the Japanese and Chinese, and for twenty or more to English-speaking sport fishermen, it is only recently that American ichthyologists have recognized this species in the Pacific while its presence in the Indian Ocean was noted only very recently. The occurrences at Ceylon, west of the Maldivé Islands, at Moçambique, and at Mauritius are all first records for those areas.

Several workers (Rivas, 1956; Royce, 1957) have considered the Pacific and Indo-Pacific blue marlins to be identical, and indeed they could not be distinguished on the basis of any external characters. However, Morrow (1957) showed, on osteological evidence, that they are distinct. In that paper, the two forms were regarded as subspecies, but accumulation of more material indicates that each form should be given specific rank. It is therefore appropriate to suggest popular, vernacular names. The Atlantic form, *Makaira nigricans*, has long been known as the "Atlantic blue marlin." Since *Makaira mazara* has now been shown to occur in both the Pacific and Indian Oceans, it is logical to follow the suggestion of Col. John K. Howard, and term this species the Indo-Pacific blue marlin."

It is a pleasure to acknowledge the generous support provided by Dr. Wendell W. Anderson, Thomas Shevlin, Alfred C. Glassell, and Col. Howard.

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DECARBOXYLATION PATHWAYS OF AMINO ACIDS IN FISH TISSUE

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ABSTRACT

Preformed amines appear to be absent from fresh fish liver, spleen, testis, stomach and somatic muscle. After two months frozen storage fish muscle showed only slight formation of ethanol soluble, ninhydrin positive compounds.

Aerobic or anaerobic incubation of fish tissue homogenates produced amine bands only in fish spleen homogenate. Similar bands appear in incubated rat spleen homogenates.

Ninhydrin reacting compounds are present in increasing amounts in fish gonads, stomach, muscle, liver and spleen. Aerobic or anaerobic incubation produced an increase in ninhydrin positive compounds only in homogenates of spleen among fish organs tested.

Fish tissues appear to contain more ninhydrin positive compounds than similar tissues of the rat.

Fish liver homogenate degrades histamine and serotonin more effectively than does rat liver homogenate.

INTRODUCTION

Because fishes are analyzed primarily as related to food technology and nutrition, the chemical knowledge of other tissues—with the exception of muscle—is very incomplete (Love, 1957). For the same reason, metabolic studies in this field are rare.

Concerning the free amino acids, histidine was found to be a normal component of muscle tissues in several marine species (470% mg in tunny; 200% mg in mackerel) and the formation of histamine during spoilage, by very active marine bacteria, is considered to be the cause of poisoning after ingestion of spoiled fish. A review of this subject and in general of the chemistry and metabolism of the nitrogenous extractives in fish, is given by Shewan (1951).

A simple paper chromatographic survey technique (Claudatus, *et al.*, 1957) was used in the present preliminary study on the decarboxylation of amino acids and of the further degradation of amines in different fish tissues.

The authors wish to express their appreciation to Dr. J. Ernest Ayre for his interest and support and to thank Miss M. D. Bellomy for her help in this work and for procuring the material and Captain William B. Gray for supplying the fishes.

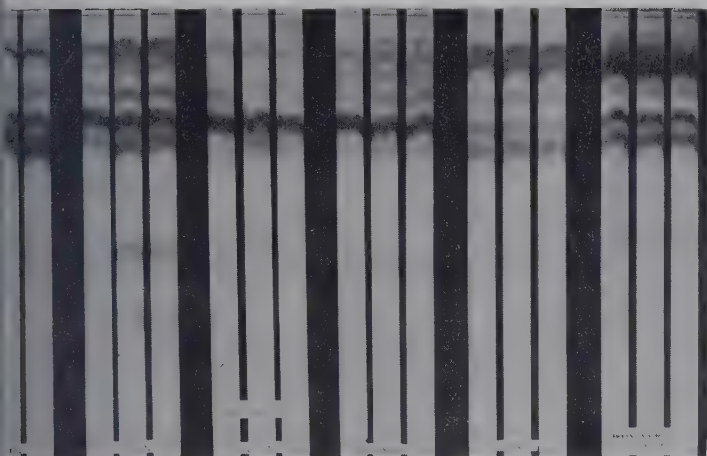


FIG. 1. In each group of three strips, the first strip has the nonincubated muscle; the second, N_2 incubated; the third, O_2 incubated. The last group of strips is of the muscle maintained in a freezer for four weeks.

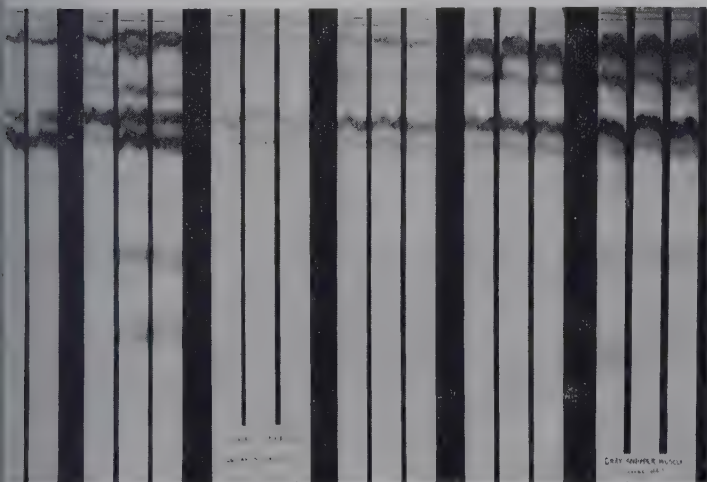


FIG. 2. In each group of three strips, the first strip has the nonincubated muscle; the second N_2 incubated; the third, O_2 incubated. The last group of strips is of muscle maintained in a freezer for seven weeks.

METHODS

Amberjack (*Seriola dumerili*) and gray snapper (*Lutianus griseus*) were dissected immediately after death. The separated tissues (liver, spleen, testis, ovaries, stomach and muscle) were homogenized with ice-cold M/15 phosphate buffer pH 7.5 (1:2). For the tissue blank 0.4 ml of homogenate 0.4 ml pyridoxal phosphate (0.1 mg/ml) and 1.2 ml phosphate buffer pH 7.5 was added.

The samples containing serotonin and histamine, respectively, were obtained by adding to 0.4 ml homogenate, 0.4 ml pyridoxal phosphate, 0.4 ml M/50 of the corresponding amine and 0.8 ml phosphate buffer pH 7.5. The amine blanks were prepared by mixing 0.4 ml M/50 amine with 0.4 ml pyridoxal phosphate (0.1 mg/ml) and 1 ml buffer.

For the samples incubated under N_2 and O_2 , incubation time was 2 hours at 37°C., in shaking incubator. All samples, incubated and non-incubated, were added with 5 ml ethanol-acetic acid (9/1), centrifuged, and 2 ml of the supernatant was evaporated in vacuum over NaOH pellets. The residue was picked up in 1 ml ethanol (95%) and

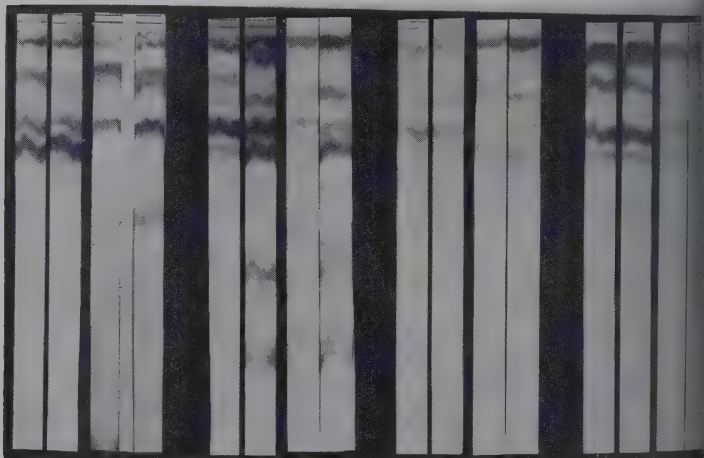


FIGURE 3. In each group of four strips, the first strip has gray snapper non-incubated tissue; the second strip, gray snapper N_2 incubated tissue; the third, nonincubated rat tissue; the fourth, N_2 incubated rat tissue. The first group of four strips has liver tissue; the second, spleen; the third, testis; the fourth, muscle.

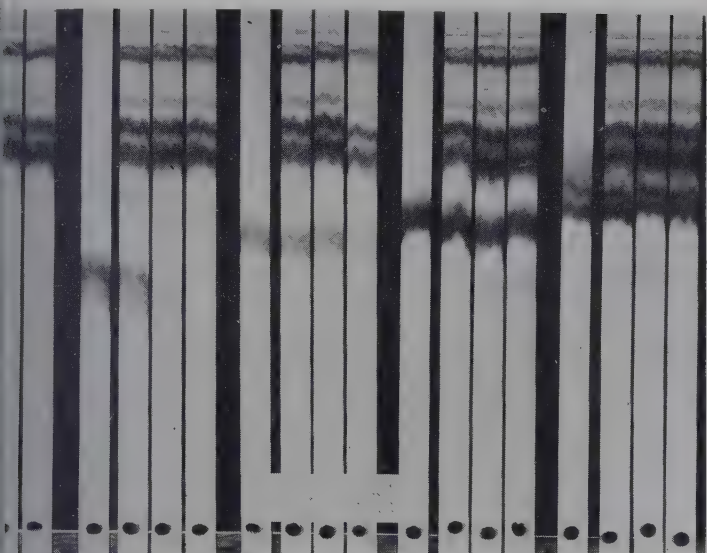


Fig. 4. The first group of three strips has nonincubated, N_2 incubated and incubated amberjack liver tissue blanks. In each following group of four the first strip has the substrate blank; the second, liver homogenate added the substrate and nonincubated; the third, the same, but N_2 incubated; the fourth, the same, but O_2 incubated. The order of substrates is serotonin, histatryptophan, kynurenine.

fused; 0.25 ml clear supernatant was spotted under N_2 stream chromatman No. 1 chromatographic strips 1 x 20 in.; evaporation was aided by infrared heat. The strips were developed by descending chromatography, in a chromatocab, using propanol/water 5/1 as a solvent (Kay, *et al.*, 1956). After drying, the chromatograms were developed with 0.25% ninhydrin in butanol and heated in an oven for 10 min. at 65° C.

RESULTS

In the chromatographic strips presented, the upper half of the bands correspond mainly to amino acids and the lower half to amines. Figures 1 and 2 show that no pre-formed amines are present in appreciable amounts in fresh fish tissues or in the muscle maintained for 1-2 months. After incubation, two bands appeared in the lower part of the strips, indicating decarboxylation

of amino acids. The position of these bands (probably primary amines) was the same for both species of fishes (Rf 0.400 and 0.530, using propanol/water 5/1). The same bands also appear in spleen, as shown in Figure 3.

In both species, the order of the increasing amount of ninhydrin reacting compounds is as follows: Genital organs, stomach, muscle, liver, spleen. An increase in the amount of ninhydrin reacting compounds after aerobic or anaerobic incubation was observed only in spleen (Figures 1 and 2).



FIGURE 5. The first group of three strips has nonincubated, N_2 incubated, O_2 incubated gray snapper liver tissue blanks. In each following group of strips, the first strip has the substrate blank; the second, liver homogenate acidified with the substrate and nonincubated; the third, the same, but N_2 incubated; fourth, the same, but O_2 incubated. The order of substrates is serotonin, histamine, tryptophan, kynurenine.

Figure 3 shows that fish tissues have a greater number of strong bands of ninhydrin reacting compounds than the corresponding rodent tissues, with the exception of the testis, indicating that fishes have more free amino acids than rodents.

Figures 4 and 5 show that in both species of fishes, the liver meta-

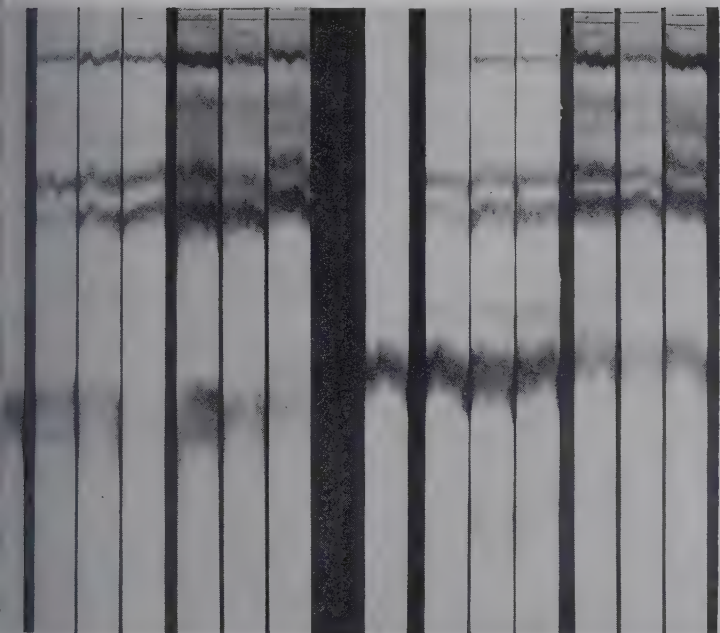


FIGURE 6. In each group of seven strips, the first strip has the amine blank; the second, mouse liver added with the amine, nonincubated; the third, the same, N_2 incubated; the fourth, the same, O_2 incubated; the fifth, sixth and seventh strips correspond to No. 2, 3 and 4 strips, but are of snapper liver. In the first group of seven strips, the experiments have been done with serotonin and in the second group, histamine was used.

When added serotonin or histamine, indicating the presence of the corresponding enzymes (amine oxidases, etc.). Added tryptophan is not metabolized appreciably in 2 hours of aerobic or anaerobic incubation with fish liver homogenate. In the gray snapper, added kynurenine appeared after incubation but it did not disappear in the Amberlite column, indicating the kynurenine degradation is species dependent. The degradation of serotonin and histamine in fish liver is stronger than in rodents, as shown in Figure 6.

SUMMARY

1. No appreciable amount of pre-formed amines was found in the fresh fish tissues studied (liver, spleen, testis, stomach and muscle).

Muscle tissue, stored in a deep-freezer 1-2 months, shows only slight formation of 95% ethyl alcohol-soluble ninhydrin reacting compounds (in the lower part of the strip corresponding to the anterior region).

2. After anaerobic or aerobic incubation of the above-mentioned tissue homogenates, only in the spleen have 2 strong bands appeared in the lower part of the strips. Position of the bands was the same for both species of fishes (Rf 0.400 and Rf 0.530, using propanol/water 5/1). The same bands also appear in rat spleen, after incubation.

3. In both species of fishes, the order of the increasing amount of ninhydrin reacting compounds is as follows: Genital organs, stomach, muscle, liver, spleen. An appreciable increase in the amount of ninhydrin reacting compounds after aerobic or anaerobic incubation was observed only in the spleen.

4. Compared to corresponding rat tissues, a greater number of stronger bands of ninhydrin reacting compounds are present in fish tissues.

5. The anaerobic and aerobic degradation of histamine and serotonin added to the fish liver homogenate is stronger than that observed in rat liver homogenate.

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OBSERVATIONS ON THE BEHAVIOR OF THE PTEROPOD *CRESEIS ACICULA* RANG

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ABSTRACT

Descent velocities of anesthetized and non-anesthetized specimens of the pteropod *Creseis acicula* Rang were compared. Anesthetized specimens with wings extended descended in a vertical position at a greater velocity than non-anesthetized specimens which invariably descended in a vertical position. Anesthetized specimens in which the animal was withdrawn into the shell descended in a horizontal position at a slow velocity. Non-anesthetized animals were observed to change their rate of descent. Rate of descent is probably controlled by the angle, pitch and horizontal breadth of the wings.

Pteropods have wing-like appendages, which are modifications of lateral lobes of the foot, on either side of the head. The manner in which these wings are flapped during forward movement has given the common name sea-butterflies to these minute pelagic gastropods (fig. 1). In some pteropods the wing-like extensions also form an



FIGURE 1. Photomicrograph of ventral end of *Creseis acicula* Rang in horizontal position on glass slide with wings in swimming attitude. Magnification x 42. Photograph taken with polaroid type 46 projection film and phase microscope.

important part of the feeding mechanism (Hardy, 1956; Moore, 1954). This paper reports another usage of the wings, the control of the rate at which the pteropod descends through water. Knowledge of the mechanisms by which zooplankton ascend and descend may aid in determining the relative importance of the complex environmental factors such as temperature, light and pressure which seem to control the vertical distribution and diurnal migration of zooplankton (Moore and O'Berry, 1957).

During the early mornings of July 15-18, 1958, the pteropod *Creseis acicula* Rang, which bears a narrow cone-shaped shell, occurred in abundance in plankton flowing into Corpus Christi Bay through Aransas Pass, Texas. Living specimens were placed for observation in a glass cylinder having an inside diameter of 14 centimeters and containing a column of water 45 centimeters in height. Individuals were observed to swim from the bottom of the vessel to the surface of the water by rapidly flapping their wings while maintaining the long axis of the shell in a vertical position. Whenever wing motion ceased the specimens would slowly descend through the water with outstretched wings seemingly checking the velocity at which the animals descended (Fig. 2). In order to determine if the outstretched wings were actually slowing the rate of descent, the following experiments were performed:

1. The velocity at which 24 living specimens with their wings outstretched and the long axis of the shell in a vertical position descended through the lower 20 centimeters of water in the cylinder was measured using the sweep-second hand of a wrist-watch for timing (Table 1).
2. The velocity at which 15 specimens anesthetized with a 0.1% solution of chlorotone descended through the same water column was measured (Table 1). These specimens became anesthetized with their wings projecting from the shell in a seemingly relaxed position. These shells descended in a vertical position.
3. The velocity of descent of 18 anesthetized specimens was measured in the same manner as above (Table 1). These specimens, by chance, had become anesthetized with their bodies withdrawn into the shell and descended through the water with the long axis of the shell in a horizontal position.

All the non-anesthetized animals and the animals anesthetized with wings extended descended with the shell vertical. All animals anesthetized with body withdrawn descended with the shell horizontal. (Continued)

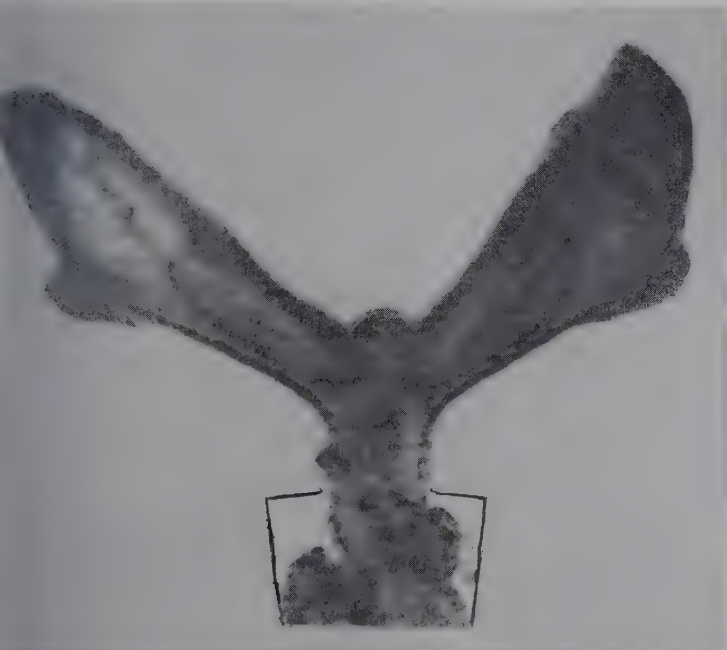


FIGURE 2. Photomicrograph of ventral end of *Creseis acicula* Rang in horizontal position on glass slide with wings outstretched as when descending through water. During descent the wings are pitched in the same direction. Magnification, $\times 42$. Photograph taken with polaroid type 46 projection film and phase microscope.

specimen anesthetized with body withdrawn recovered and extended body during descent. The shell at this time immediately went from horizontal to vertical attitude.

The specimens which became anesthetized with wings extended descended more rapidly than did the non-anesthetized specimens even though the position of the shell was the same under each condition. The mean descent velocities were different at the 5% probability level. This is interpreted as indicating that living specimens are able to regulate their rate of descent probably by manipulating the angle, pitch, and horizontal breadth of the wings. This interpretation was supported by the behavior of individual organisms which were observed to first descend rapidly, then more slowly, and then again rapidly.

The anesthetized specimens with body withdrawn descended more slowly than the anesthetized specimens which descended with the shell in a vertical position. This is very likely because the shell presents poor streamlining when descending in a horizontal position. The mean velocity of descent of non-anesthetized forms were not statistically different at the five per cent probability level from the mean velocity of descent of the anesthetized shells which descended with the long axis horizontal.

TABLE 1
VELOCITY OF DESCENT OF *Creseis acicula* RANG (CM/SEC.) ^{1, 2}

Item	Non-anesthetized Specimens	Anesthetized Specimens	
		Long axis vertical during descent	Long axis horizontal during descent
Number of specimens	24	15	18
Mean descent velocity	1.15 cm/sec.	1.55 cm/sec.	1.05 cm/sec.
Standard deviation	0.31 cm/sec.	0.36 cm/sec.	0.19 cm/sec.
Variability	27	23	18
Observed range	0.72-1.80 cm/sec.	1.11-2.50 cm/sec.	0.83-1.34 cm/sec.
2 standard errors of the mean	0.13 cm/sec.	0.18 cm/sec.	0.09 cm/sec.

¹Temperature and salinity of the water was 31 deg. C. and 33.9 parts per thousand respectively.

²Specimens varied in length from 3.5-6.5 mm. Length of specimen did not seem to affect velocity of descent.

It is interesting to speculate concerning reasons for the behavior of this pteropod. *Creseis* has two ways in which to try to escape from its enemies. It may retract its body inside of the shell or it may flee. Although retraction of the body inside the shell might be able to protect the soft body of *Creseis* from small predators, it affords no protection from those animals which swallow the animal whole. In order to escape large animals, *Creseis* must flee. The velocity at which the specimens of *Creseis acicula* ascended through 45 centimeters of water at a more or less steady pace was measured to be 1.28, 2.5, and 3.5 centimeters per second, respectively. These animals were able to ascend more rapidly by swimming than they were able to descend through the water by gravitational pull. It would seem therefore that *Cre*

could escape its enemies more readily by swimming than by any other means. However, observations in the laboratory indicate that the shell of these animals maintains a vertical position during swimming and the principal direction of movement is upward and there is relatively little lateral change of position by swimming. Also descent is always by the parachute-like action described above. Occasionally an individual near the water surface would perform a loop after which it could descend, but, otherwise, all swimming motion was confined to the animal remaining stationary in the water column or ascending. In order to test the reaction of *Creseis* when disturbed, several specimens, which were maintaining themselves near the surface, were tapped lightly with a pencil. They momentarily retracted their bodies inside the shell but then extended their wings and "parachuted" to the bottom. As most pteropod predators probably live near the surface, the principal direction of escape for the pteropod is down. Therefore, the method by which the descent is made assumes importance as a possible escape mechanism. The animal is able to maintain the shell in a vertical position by extending the body outside of the shell. This permits more rapid descent than if the body were withdrawn and the shell allowed to descend in a horizontal position. In nature, the animal is not observed to make use of the additional velocity made available by descending in a vertical position, but, on the contrary, slowed down its rate of descent by wing manipulation.

Oppenheimer (personal communication, 1958) has observed that the mouthparts of *Creseis a.* continue to operate even though the wings are not in motion. Perhaps pteropods slow their descent when passing through a particular nutritious stratum of water. However, this could not have been the reason for the variation in descent velocities observed in the laboratory in essentially homogeneous water.

In conclusion, it appears that when the wings of *Creseis acicula* are extended the shell of this organism is able to maintain a vertical position during descent. The rapidity at which the descent is made seems to be controlled by the attitude of the wings. Faster descent is possible with the shell vertical than horizontal with the animal withdrawn into the shell. Horizontal descent does not seem to take place in nature. It has been postulated in this note that the behavior of *Creseis acicula* during descent might be an escape mechanism or related to feeding habit.

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The degree of comprehensiveness of the bibliography is to a large extent dependent upon the cooperation of workers in the Marine Sciences of this area. *It is therefore hoped that individuals and organizations will aid by sending copies of all relevant publications to the Editor.* Any omissions brought to the attention of the Editor will be included in subsequent issues.

It has been found convenient to use a modification of the classification used by the Journal du Conseil Bibliography for present purposes. The Editorial staff wishes to acknowledge the valuable assistance given by a number of investigators in compiling the bibliography.

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